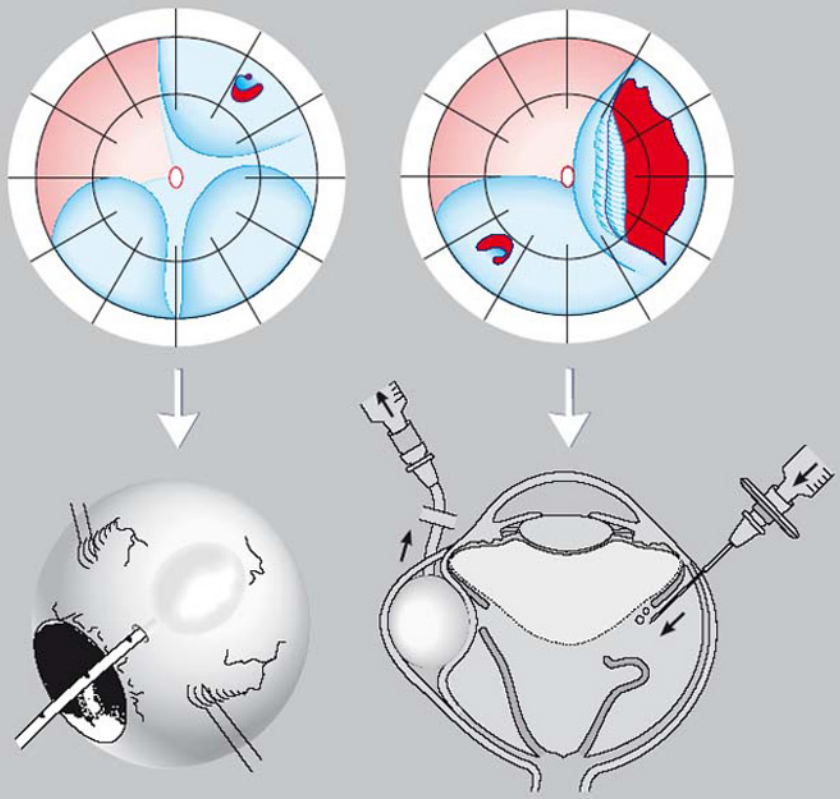
A Practical Guide to

Minimal Surgery for Retinal Detachment

2

Temporary Tamponades with Balloon and Gases without Drainage · Buckling versus Gases versus Vitrectomy · Reoperation · Case Presentations

Ingrid Kreissig



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Volume 2

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To Harvey,
the most perceptive thinker in this field,
who has inspired my enthusiasm for retinal surgery
for over 30 years.
He is the one who should have written this book.

To my father,
a most kind and gracious person, who always supported
my wish to study medicine and who provided his wisdom
and good advice during the subsequent years.

And to Else Zenz,
a most generous person, who awakened in me
the interest in medicine
and the desire to become a doctor.

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Preface

The book describes the Art of a minimal extraocular approach for various retinal detachments. It has a flexible cover, fits in the pocket of a doctor's coat, and is meant to be at hand for the retinal surgeon at any time. It reflects everyday practice, i. e., the problems with which a doctor might be confronted and provides checklists on how to cope with these problems. The book is a result of 30 years' experience in research, teaching, and clinical work in retinal detachment surgery.

The book comprises 6 chapters, adding up to 370 pages, which are illustrated with 233 mostly colored computer drawings. It is written in an easy-to-understand fashion and in a dialogue style. Anybody accustomed to underlining important passages will find that important facts are already in bold script or emphasized in red boxes. The clearly structured layout of the book should encourage its use as a hands-on guide.

In the chapter on the balloon procedure the reader is taken step by step from its use for uncomplicated to complex detachments. The chapter on the gas operations is conceived for the retinal practitioner and surgeon: It first explains the physical properties and biological effects of the expanding gases. This knowledge is then transferred to clinical situations and to the wide range of their applications. Instructive illustrations are provided for better understanding and for important facts to be looked up at rounds or in the operating room. Diagrams demonstrate how to apply the various gas techniques for different retinal detachments not suitable for external buckling. But the retinal tear is always in the center of any treatment concept. The aim is to perform a minimal extraocular approach, even if several small steps are needed for reattachment of complex configurations of tears.

In seperate chapters the present techniques of reattachment surgery are discussed and compared, i. e., the extraocular procedures of minimal buckling (balloon, segmental sponges) with the intraocular approaches (gases, primary vitrectomy). They are evaluated with reference to morbidity and reoperations. The reader is integrated into the ongoing discussion concerning their pros and

cons. The last chapter on reoperation represents the ultimate realization of a minimal extraocular approach. Here as well the message is: Find and close the break, do not add prospective surgery, and try to stay out of the eye as much as possible, i.e., with a minimum of surgical trauma.

The aim is to reduce the morbidity to a minimum. Consequently: "A small operation is better than a large one, two small procedures are better than a large one, and this is even true for an eye up for reoperation."

Clearly laid-out guidelines, easy-to-use checklists, and additional Rules of how to find the break in a rhegmatogenous surgical failure will assist the retinal surgeon in this challenging goal to practice minimal extraocular surgery for retinal detachments.

Tuebingen, Summer 2000 *Ingrid Kreissig*

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9 Temporary Balloon Buckle without Drainage: Minimal Extraocular Surgery for Retinal Detachments with 1 Break or Breaks within 1 Clock Hour

9.1 Introduction

Minimal extraocular surgery for retinal detachments, consisting of an elastic segmental buckle (sponge) and cryopexy to the break without drainage of subretinal fluid, has already significantly reduced the complications of surgery [1–6]. As you recall, the complications of sponge buckling were extraocular, i.e., sponge extrusion, diplopia, and infection of the explant.

● **The balloon procedure, which we will now discuss, represents a further swing towards minimal surgery:**

1. It eliminates the last complications of the non-drainage procedure.
2. It can return an eye with a detachment to the state that existed immediately after the break occurred when it could have been treated with laser or cryopexy alone.

? **How should one provide only a temporary buckle precisely placed under the break without fixating sutures?**

▶ This was the premise to reduce surgical trauma and the remaining potential complications of the non-drainage buckle procedure (see Part 1, Chapter 8.14, pp. 224–231).

9.2 History

From 1972 to 1978 Lincoff, Kreissig, and the retinal fellows were looking for a way to maintain a temporary indentation beneath a retinal break in a small detachment. We thought that if the indentation could be sustained for a few hours, subretinal fluid would be absorbed and the retina would return to the state that existed immediately after the tear occurred. This would make laser coagulation alone sufficient for sustained reattachment. With this in mind a number of devices were designed and tested over 5 years on animals. The devices were all extraconjunctival and fixation was a problem.

In this context, let us recall: Sponge buckles are fixed by scleral sutures and they obtain their indentation by tying the sutures under tension to compress the sponge. Transconjunctival scleral sutures proved possible in rabbit eyes [7] and were tried on the eye of an elderly patient with thin epibulbar tissues. However, the pressure of the sponge (and of other extraconjunctival devices tested) caused erosion of the conjunctiva beneath the sponge.

? What was the logical consequence?

? To give up the search for a temporary buckling device without opening conjunctiva?

▶ **No**, instead only the approach was changed, i.e., from extraconjunctival to subconjunctival.

Due to the secondary erosion of conjunctiva by various extraconjunctival devices, the idea of inserting a buckle device through a small opening in conjunctiva occurred to us as a possibility.

? How should a device—that would yield a buckle of 8 to 12 mm in diameter—be inserted through a small conjunctival opening of 1 to 2 mm?

? A pliable elastic device, such as an intraocular lens through a small entrance site?

▶ **No**, instead another idea came up.

? Think for a moment, what would you suggest?

Of the possibilities, the best proved to be a thin elastic balloon on the end of a soft silicone tube that was 1.8 mm in diameter. It was a balloon catheter, similar to those used in urology and later in cardiology. The first balloon catheter, which was hand-made by Lincoff, measured — including the deflated balloon — 2.5 mm in diameter. This was acceptable, since the conjunctival incision for insertion could still be quite small. The first part of the problem, how to keep the conjunctival opening small, was solved.

? Now the next part of the problem had to be solved:
- **How to localize precisely the balloon after insertion of the catheter?**
- **With sutures?**

▶ **No**, because this would require more extensive surgery and incur risks during placement of intrascleral sutures. In addition these sutures would have to be removed eventually due to the temporary nature of the buckle.

? Which alternative would you suggest to solve this problem?

▶ **The problem of fixation of the parabulbar balloon without sutures was solved by:**
1. The large size of the balloon after inflation.
2. The elasticity of the balloon (see Chapter 9.3).

The first balloon was made of latex and proved to be too reactive in the tissues. Subsequently, a balloon of silicone [7] was tried, but it proved to be too fragile. Finally a latex balloon with a silicone coating proved to be ideal. The latex provided the strength and elasticity and the silicone the tissue inertness. This balloon catheter has been reduced in size to 1.5 mm in diameter. The final model has been named the

● **Lincoff–Kreissig Balloon** [8]:
1. It has a steel stylette that stiffens the catheter during insertion and enables precise control for positioning in the parabulbar space.
2. There are calibrations on the catheter that facilitate measuring the distance of the inserted balloon from the limbus (Fig. 9.**1**).

An adapter at the proximal end of the catheter contains a valve that retains fluid. The valve is open when a standard syringe is inserted and it is closed when the syringe is withdrawn. Postoperatively the size of the balloon can be increased by injecting additional fluid.

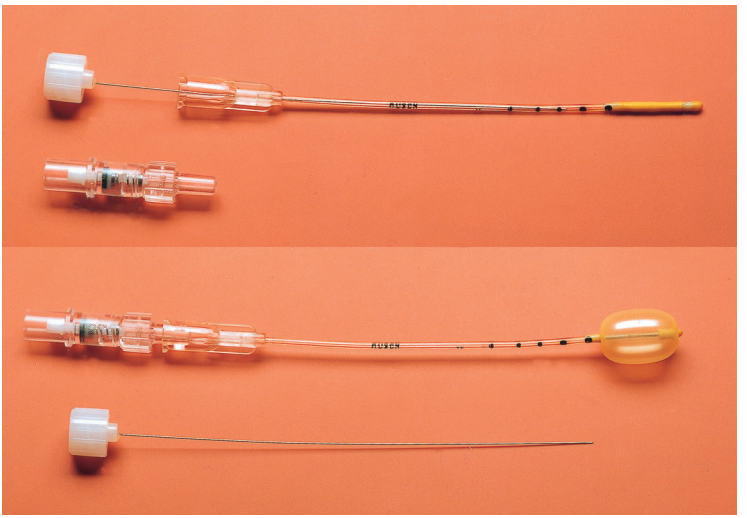


Fig. 9.1 Lincoff–Kreissig Balloon. The balloon has a metal stylette to facilitate insertion into the parabulbar space and calibrations (black marks) on the tube to enable a more precise determination of the balloon's position in the parabulbar space. *Top:* Deflated balloon catheter with stylette in place; beneath it the adapter. *Bottom:* Inflated balloon (0.75 ml of sterile water) with self-sealing valve in place; beneath it the withdrawn stylette.

The balloon can be removed from the eye by deflating the balloon and pulling gently on the catheter.

- **The balloon catheter comes in 2 lengths:**
  90 mm for inferior breaks and
  125 mm for superior breaks
  (see Chapter 9.4, p. 9).

9.3 Principle of the Balloon Procedure

The mechanism of the temporary balloon [9–17] is the same as that of any other elastic buckle, such as the sponge cylinder or the elastic pouch (see Part 1, Chapters 8.1, pp. 126–127 and 8.8.2, page 181).

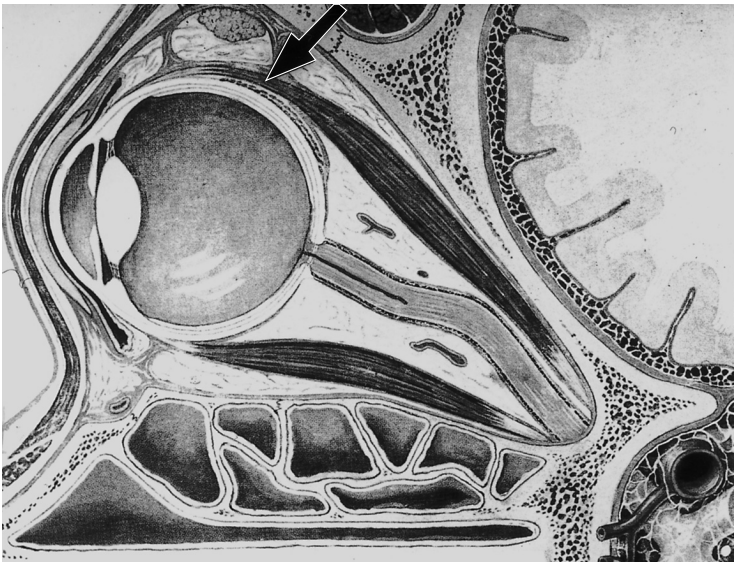


Fig. 9.2 Sagittal section of the globe and neighboring structures. The parabulbar balloon will be positioned between the bony orbit and the globe (see arrow).

? But one has to accept a number of premises before accepting the balloon procedure: What are they?

1. Subretinal fluid will absorb if the break is buckled.
2. The inflated balloon, not anchored by sutures, will provide a reliable buckle and remain in the correct position beneath the break for the period in which retinal adhesion forms.
3. After 1 week the retinal adhesions around the break, induced with cryopexy or laser, will be strong enough to secure the break after removal of the balloon buckle (see Part 1, Chapters 7.2.2 and 7.2.3, pp. 98–110).

If you are convinced of these 3 premises, then the balloon procedure, implying a temporary unfixed buckle, becomes a logical operation.

Now a question you might raise:

? How does the parabulbar balloon maintain the correct position in the orbit (Fig. 9.2) in the absence of fixating sutures and provide adequate tamponade of the break for at least 1 week, the time needed for an adequate adhesion to develop?

▶ Here are the facts:

After inflating the inserted balloon, it is initially compressed between the eye and the bony orbit (Fig. 9.**3**). Intraocular pressure is increased (the central artery has to be checked for patency!). The eye is not static, but is dynamic. Intraocular pressure will return to normal within 1 to 2 hours. As the eye decompresses under the pressure of the balloon, a deeper indentation in the globe is created into which the balloon expands and from which it does not move after ocular rotations are restored (Fig. 9.**4**).

● And this is the secret of how the parabulbar balloon is fixed in the absence of scleral sutures.

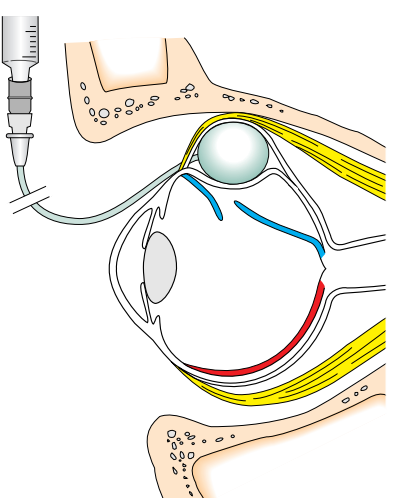


Fig. 9.**3** Sagittal section of the orbit showing the balloon in Tenon's capsule shortly after insertion. The balloon is compressed (it has a slightly oval shape) between the globe and the bony orbit. The intraocular pressure is increased.

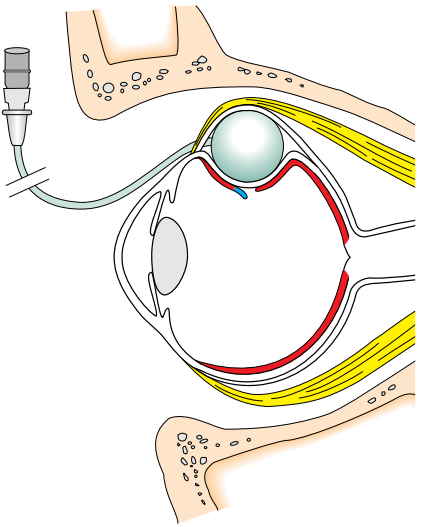


Fig. 9.4 Sagittal section of the orbit showing the balloon in Tenon's space after the eye has decompressed and the balloon has expanded to a round shape and closed the retinal break. The retina has reattached and the break is ready for laser treatment.

Thereafter the balloon buckle acts like a large silicone sponge to close the retinal break and cause subretinal fluid to be absorbed.

? Now what is new with the balloon procedure?

▶ 1. No fixating sutures are needed.
2. The balloon is withdrawn after 1 week, i.e., it represents only a temporary tamponade for the period in which a retinal adhesion of sufficient strength develops to secure the break.

? A consequence of the balloon procedure is that the last 3 complications of segmental buckling, sponge extrusion, diplopia, and infection are eliminated. Why?

▶ Simply because the balloon is only temporarily present.

9.4 Instrumentation and Surgical Technique

The preparation of the eye for surgery is the same as that for a segmental buckle operation (see Part 1, Chapter 8.2, pp. 127–128). However, less instruments are needed for the balloon procedure (Fig. 9.**5**). As a rule only flat instruments are used, except for the forceps (Castroviejo) used to grab the very anterior muscle insertion to place a transconjunctival/episcleral traction suture. Of course, prior to surgery you should check your cryoprobe, test the freezing capacity of the cryo instrument and set the temperature you will apply at around –40° to –60°C (see Part 1, Chapter 7.5.2, pp. 118–120).

The balloon procedure can be performed with parabulbar, subconjunctival, or topical anesthesia. After insertion of the speculum, 2 traction sutures are placed in the muscle insertion (the 2 muscles neighboring the retinal break) to rotate and stabilize the eye during cryopexy and localization of the break.

Fig. 9.**5** Instruments for balloon operation. *Top* (horizontal items from left to right): Wire speculum, suture for traction sutures through muscle, cigars and Q-tips, Castroviejo forceps, needle holder, Bonn spatula (narrow). *Bottom* (vertical items from left to right): Scleral marker, balloon consisting of: metal stylette, balloon catheter, syringe filled with sterile water and yellow adapter, Castroviejo calipers, Bonn forceps blunt, Kreissig depressor, Kreissig balloon forceps (siliconized), Westcott scissors blunt.

- To reduce the slight possibility of conjunctival dislocation when pulling on the traction sutures, the sutures should be placed very anterior at the tendonous insertion, where dislocation of conjunctiva by pulling is unlikely.

? Now how should the posterior border of the break be localized on conjunctiva?

▶ As you recall: The key to reattachment with a non-drainage procedure is a most precise localization of the detached break, this time however, **on unopened and mobile conjunctiva**; this is more difficult than on the sclera.

The retinal break is localized with the cryoprobe by depression, its position marked with gentianviolet on the conjunctiva and its distance from the limbus measured.

- **However, when performing this maneuver you have to circumvent the following 2 problems:**
  1. The parallax of the detached break.
  2. The mobility of the posterior conjunctiva.

- **The following measures will be helpful for overcoming the problems of parallax:**
  1. Localize the retinal break from a position diametrically opposite to the break with the cornea in horizontal position, i.e., not tilted.
  2. Avoid unnecessary circumferential dislocation of mobile conjunctiva by rotation of the eye. This can be achieved by placing the cryoprobe first at the ora serrata in the correct clock hour and then moving it radially towards the break by holding it in vertical position to the globe.
  3. After this:
     During the moment of the **localizing freeze, the *mobile conjunctiva becomes temporarily fixed to the underlying tissues.***
     This is the moment for an exact marking on conjunctiva, i.e., not being jeopardized by an accompanying slippage of the conjunctiva.

With these measures, the circumferential parallactic miscalculation of the detached break can be reduced to a minimum. Miscalculations in antero-posterior direction can be corrected by inserting the balloon 2 to 4 mm beyond the plotted posterior edge of the break as marked on the conjunctiva.

? Why is the balloon inserted more posteriorly?

▶ Because, if after insertion the balloon catheter appears to be too posterior, but in the correct radian, it can be pulled anteriorly as needed under ophthalmoscopic control without difficulty.

Since the conjunctiva will immediately become mobile after thawing of the posterior freezing mark, it is helpful to add 2 additional anterior marks in the radian of the break during this cryogenic fixation: 1 mark at 7 mm anteriorly and another 1 at the limbus. This defines the radial axis of the break (Figs. 9.**6 a, b, c**).

? Keep in mind that the anterior localization of the radian of the break is less liable to error. Why?

▶ Because the anterior conjunctiva (being fixed at the limbus) does not move as readily as the posterior conjunctiva.

If the break is beyond the limits of the conjunctival cul-de-sac, only the radian of the break is marked and the antero-posterior distance is estimated. Localization of such a break is difficult and should only be done after some experience with this procedure. As mentioned, precise transconjunctival marking of a posterior break can be compromised by the mobility of the conjunctiva.

? Before inserting the balloon catheter do you have to prepare it in a special way?

▶ **Yes, in the following way:**
- First test the balloon with sterile water (not balanced salt solution, because the crystals of salt might compromise the valve and cause subsequent leakage).
- Then fill and empty the catheter several times until all of the air bubbles are removed.

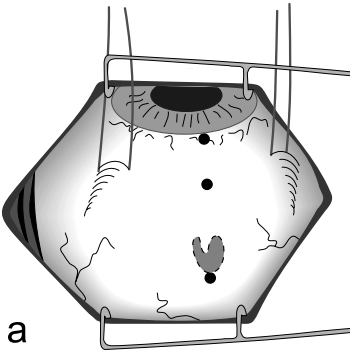
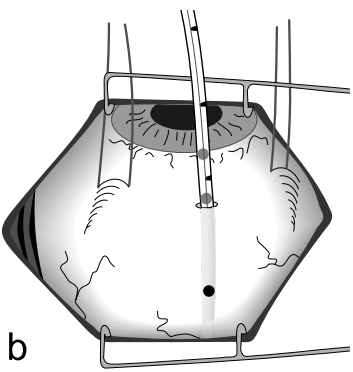
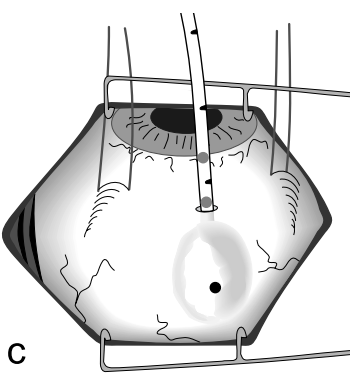


Fig. 9.**6 a** The location of the posterior edge of the break is marked. Anterior to it are 2 additional marks: 7 mm anterior (in the area of the muscle insertion) and at the limbus. They determine the radian of the break.



b The conjunctiva is opened 6 mm anterior to the mark of the break and the deflated balloon catheter with the stylette in place is inserted. The balloon catheter is in correct radian, since the 2 anterior conjunctival marks lie under the exiting portion of the catheter. The metal stylette will be subsequently withdrawn.



c The balloon catheter has been inflated and become visible as a bulge under conjunctiva. The 2 more anterior conjunctival marks (appearing grayish) are visible beneath the transparent catheter indicating its correct radial position. The central artery has to be checked for patency.

? Why is this necessary?

▶ Because the air would diffuse through the thin membrane of the inflated balloon and, to your surprise, the next morning the balloon would appear almost empty.

Next the metal stylette is placed into the catheter to stiffen it and the balloon is ready for insertion. Prior to this, a 2-mm incision in conjunctiva (approximately 6 mm anterior to the mark of the break) is made in the radian of the break. First, the curved end (with the small knob) of the Kreissig depressor (Fig. 9.**7**) is inserted beneath Tenon's capsule and moved posteriorly to free a passage for the balloon catheter. Before inserting the balloon catheter, the measured distance of the break from the limbus (e.g., 14 mm) is noted and marked with gentianviolet in the area of the calibrations on the catheter. Recall that the calibration closest to the balloon is 10 mm from its center, the next 15 mm, then 20 mm and so on.

The balloon catheter has to be handled with utmost care, preferably by using special forceps (Fig. 9.**8**). These forceps have flat ends coated with silicone and an indentation matching the diameter of the catheter. These precautions avoid injury to the balloon during its insertion. During insertion the balloon catheter can be held tightly between the ends of these forceps without the threat of damaging the balloon. Then the balloon catheter is maneuvered beneath the break. The question arising is:

Fig. 9.**7** Kreissig depressor. A depressor with 2 curved ends almost correlating with the curvature of the globe. During balloon surgery, the curved end with the little knob *(left)* is placed on conjunctiva adjacent to the inserted catheter. It provides an *ab externo stabilization* of the inserted catheter (which has become a soft and flexible tube after withdrawal of the stylette) during inflation of the balloon.

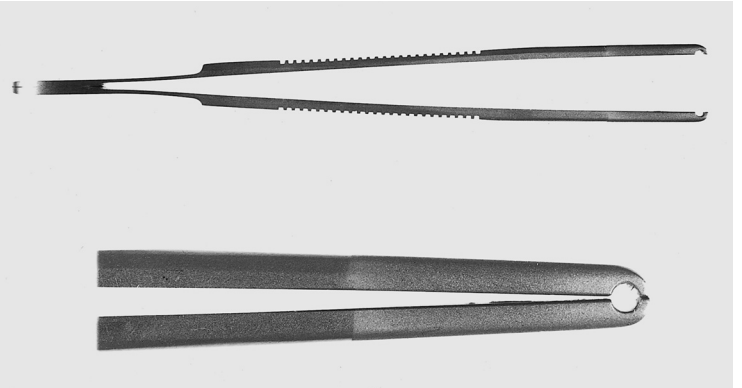


Fig. 9.**8** Kreissig balloon forceps. *Top:* The 2 open flat arms show a half-circular indentation; the arms are coated with silicone. *Bottom:* Magnification of the closed branches. An opening becomes apparent which matches the diameter of the catheter. Due to the silicone coating (lighter gray), the balloon catheter will not slip, nor become compressed or damaged when held between the branches.

? Is the inserted balloon catheter with the stabilizing stylette in place in the correct radian beneath the break?

- This can be ascertained by checking whether the 2 anterior conjunctival marks (i.e., in the area of the muscle insertion and at the limbus) lie under the exiting portion of the transparent catheter (Fig. 9.**6b**). The metal stylette is then withdrawn (Fig. 9.**6c**).
- **To avoid altering the position of the inserted catheter** when its stylette is withdrawn, place the curved end of the depressor (the end with the little knob) parallel to it on unopened conjunctiva to provide an **ab externo stabilization** [18].

After withdrawal of the stylette, the adapter with the self-sealing valve is inserted into the catheter. To make this juncture watertight—i.e., to prevent a postoperative leakage out of this area—the adapter is lubricated with sterile ointment before insertion. The balloon is inflated with 0.5 ml of sterile water. At this moment the central artery has to be checked for patency and the balloon for correct positioning.

- **If the balloon is not in an optimal position,** the balloon can be still moved easily at this point by manipulating it transconjunctivally with the curved end of the depressor.

If this does not suffice you have to re-insert the catheter.

? What can be done, if with ophthalmoscopy, the inflated balloon is only faintly or not at all to be discerned under the detached break?

▶ You are in trouble. This is one reason why you should already have sufficient experience with the non-drainage procedure by using sponges sewn onto sclera.

If the position of the balloon is correct, another 0.5 ml of fluid is injected to total 1.0 ml.

- Keep in mind:
  A balloon inflated with 1 ml of fluid has a diameter of 1.25 cm,
  —and that represents a large scleral buckle.

After full inflation (1 ml) the central artery must be checked again for patency. If it is closed, some fluid from the balloon is withdrawn until patency is restored. No sutures are placed to secure the balloon. After inflation the balloon is still slightly mobile.

? Consequently, after actually finishing with surgery, you have to be careful during the subsequent manipulations not to dislocate the still slightly mobile balloon: Which measures should be taken to prevent the risk of a secondary dislocation of the balloon at completion of surgery?

▶ 1. Cut the traction sutures of the muscles as close as possible to the conjunctiva to avert dislocation of the globe when pulling the sutures out.
2. Be careful when removing the speculum.

3. Take special care not to pull on the catheter when taping its external portion and the adapter to the patient's temple or forehead. Be sure to lead the catheter away from the cornea as it leaves the eye to avoid corneal desquamation.

- **For inferior breaks,** use the
  - **short balloon catheter (90 mm)** and
  - **lead the catheter upwards** (nasally or temporally) to the *forehead*.
- **For superior breaks** use the
  - **longer catheter (125 mm)** and
  - **lead it downwards,** then around the *lower lid*—so as not to interfere with closure of the lids—**and upwards** (nasally or temporally) to the *forehead* (Fig. 9.**9**).

It is helpful to use a different type of tape for fixation of the catheter than for the eye patch to avoid unnecessary untaping of the catheter

Fig. 9.**9** A superior break at 11 o'clock was treated with the long (125 mm) balloon catheter. The catheter is first led downwards, then around the lower lid so as not to interfere with lid closure, after that up nasally (cave corneal erosion!). The adapter and the tube are taped to the patient's forehead.

(removed after 1 week) when the eye is prepared for the daily fundus examination.

Atropine and antibiotic ointment is applied to the eye and lid margins. Both eyes are patched. The next day the balloon buckle is checked for correct placement and height: If the retina is reattached and the break stretched out on the balloon buckle (Fig. 9.**10**), the fellow eye is unpatched.

- If a larger balloon buckle is needed the next day, its diameter can be increased by another 2 to 4 mm just by injecting additional fluid through the valve that is fixed at the patient's forehead; in this situation no reoperation is needed.

If the edges of the retinal break were not treated with transconjunctival cryopexy at the time of surgery, laser lesions can be added the next day. The balloon buckle is well tolerated. Patients report little

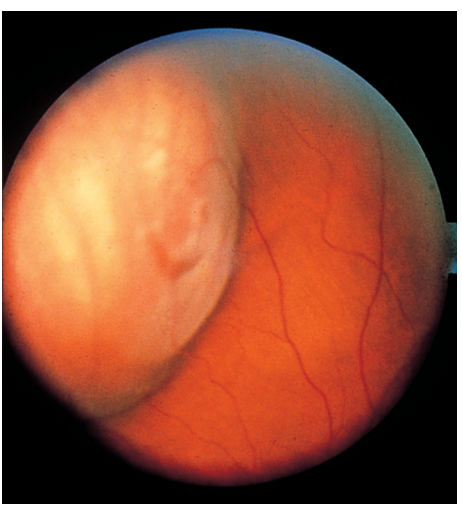


Fig 9.**10** Fundus photograph of a horseshoe tear on a balloon buckle 16 hours after insertion of the balloon catheter. The localizing cryopexy mark is still visible at the posterior edge of the break. The residual circumference of the reattached break will be sealed off with laser lesions (the alternative would be transconjunctival cryopexy around the break intraoperatively).

or no discomfort in the post insertion period, unless the tube abrades the cornea, in which eventuality the direction of the catheter has to be adjusted so that it does not cross the cornea.

- **Several hours after surgery** the threat of dislocating the parabulbar balloon during such a postoperative maneuver no longer exists.

The balloon is removed after the retinal adhesions have developed sufficient strength, i.e., after 7 to 8 days [19–21] (see Part 1, Chapter 7.2.2, pp. 98–99). Prior to withdrawal of the balloon, you should ascertain that the break is sufficiently surrounded by pigmented lesions.

? The balloon is first deflated by half its volume 1 day prior to removal: Why?

▶ To test the strength of the adhesions.

If the retina remains attached, the balloon is completely deflated and withdrawn without topical anesthesia the next day. The small conjunctival wound closes without a suture (Fig. 9.**11**).

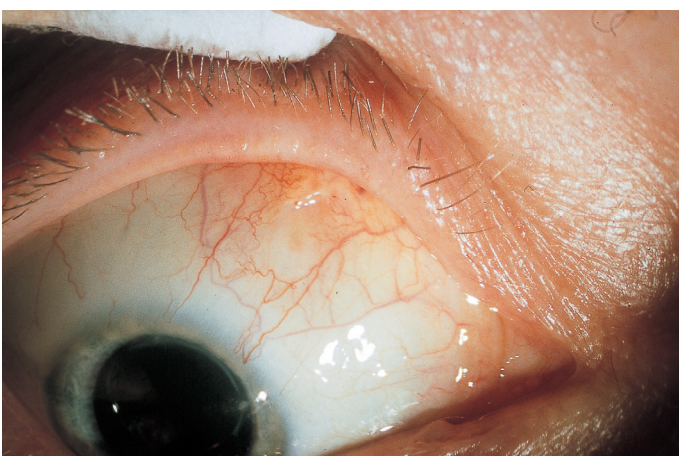


Fig 9.**11** The balloon was withdrawn after 7 days. The Fig. represents the eye a day later. The small conjunctival wound closes by itself.

9.5 Practical Tips when Starting with the Balloon Procedure

▶ **To avoid dislocation of conjunctiva when pulling on traction sutures during localization of the break**

- This can be achieved by placing a **traction suture with a short bite** (2 to 3 mm) in the **furthest anterior part of the muscle insertion.**

To identify this area, take a wet Q-tip and move it posteriorly from the insertion. The muscle insertion then becomes easily recognizable because the conjunctiva is stretched and more transparent. For the next maneuver take a sharp forceps, e.g., a Castroviejo (the only sharp instrument you will use), spread it for only 3 mm and grab the anterior muscle insertion for a transconjunctival/episcleral suture.

- **With this technique:**
  - You minimize the risk of a subconjunctival hemorrhage.
  - You will have a traction suture, which will not dislocate the conjunctiva when pulled upon.

▶ **To ascertain the correct position of the inserted catheter, i.e., in the radian of the break**

After insertion of the catheter with the stabilizing stylette in place, the 2 additional anterior localizing marks (about 7 mm anterior to the break and at the limbus) should be positioned beneath the transparent tube where it exits the incision site.

▶ **To maintain the correct position of the inserted, deflated catheter during withdrawal of the stabilizing stylette and inflation of the balloon with fluid**

Prior to removal of the metal stylette, place the curved end (with the little knob) of the depressor adjacent to the catheter on the conjunctiva to ensure an ab externo stabilization of the catheter during the removal of the stylette and the inflation of the balloon.

- Now you have to ascertain whether the correct position of the catheter was maintained during the inflation maneuver. You can do this by checking whether the 2 additional anterior localizing marks are still visible under the transparent tube of the catheter.

▶ To locate the position of an inflated balloon under the break in a bullous detachment

At the operating table, the balloon indentation may be still quite shallow. To better define its position, pull on the inflated catheter (you cannot remove it by this maneuver) and the anterior portion of the balloon indentation will become more visible identifying its radial position.

? It is advisable to position the balloon for a posterior break slightly more posterior than pre-calculated: Why?

▶ If the balloon is too posterior, but in the correct radian, after withdrawing 0.3 to 0.5 ml of fluid, it can be moved without problems anteriorly to the correct position under ophthalmoscopic control by pulling on the catheter.

In the new position the balloon can be re-inflated.

? A just inflated balloon can easily be moved anteriorly by deflating and pulling upon the catheter, *but you can never push it more posteriorly: Why?*

▶ Because the stabilizing stylette, present during insertion, is no longer in the balloon catheter.

? What should you do if a more posterior placement of an inserted balloon is required?

▶ To obtain a more posterior placement, start over again; this means, withdraw and re-insert the balloon catheter with the stylette in place.

This only takes a minute. But trying instead to push the balloon catheter more posteriorly without a stylette you will not succeed, but waste time and traumatize the eye.

▶ **To detect intraoperatively a tiny break in an eye with problematic optic media (small pupil, cataract, intraocular lens with secondary cataract, etc.)**

One day prior to surgery, after a meticulous search, let us assume that you have finally detected the tiny break.

? Intraoperatively locating such a break at the moment of freezing will be difficult and afterwards verifying the correct position of the balloon under the detached break even more difficult: Why?

▶ Your mark of the break on *mobile conjunctiva* will be not of much help.

The chances of, first not detecting the break at the operating table or, second not recognizing it after insertion of the balloon are great.

? What to do?

▶ **A better way to cope with these problems is to plan a precise and quick localization of this break 1 day prior to surgery:**

1. Make a precise (in terms of clock hour) and detailed drawing of the break and its neighboring structures (e.g., vessels).
2. Determine its distance from the ora serrata in disk diameters.
3. In special situations, mark the radian of the small break by a laser lesion of 200 to 500 µm in the pars plana (made visible by depression during laser application).

The latter preparation will be of help intraoperatively to detect the break by identifying the laser mark with depression and then moving the cryoprobe in its radian posteriorly for the pre-calculated disk diameters. Making a freezing mark in this area afterwards will likely identify the small break. In addition, the subsequent correct position

of the balloon under such a break can be best ascertained by viewing it in relation to the laser mark in the pars plana. Due to this maneuver, at least the correct radian of the break is known and only the anteroposterior position has to be estimated. Preoperatively documented adjacent features, vessels or pigment spots, will be of help.

- As an alternative:
  Do not try to mark the tiny break with large white retinal cryopexy lesions, which would imply overfreezing!

- **With the described regimen you can prevent:**
  — Unnecessary diagnostic cryopexy lesions for detecting a tiny break
  — Overfreezing to mark the area of the break by a whitening of the retina for subsequent balloon insertion.

▶ To maintain the correct position of the balloon during the period immediately after surgery

We recollect that immediately after inflation (during a period of 1 to 2 hours) the balloon is still slightly mobile, i.e., not yet trapped in a deeper indentation in the globe.

? Which maneuvers can dislocate the balloon catheter, which is still mobile directly after insertion, and jeopardize the postoperative results?

▶ **Here are some tips on how to prevent these mishaps:**

1. Do not rotate the eye when removing the traction sutures.
2. Take care not to displace or pull on the balloon catheter when removing the speculum.
3. Do not dislocate the catheter when taping it to the patient's forehead.
4. Patch both eyes (you can patch the fellow eye already before starting the operation), which is important when the balloon operation is done under topical anesthesia.

▶ **To re-position a failing balloon the day after surgery.**

Assume the day after surgery that the retina is only partially reattached, i.e., the break is inadequately tamponaded and still leaking.

First, **try to increase the size of the balloon buckle** with an additional injection of 0.3 to 0.5 ml of fluid (check central artery for patency!).

? But what if the balloon buckle is still inadequately positioned?

▶ 1 day after surgery there is no chance of changing the position of the balloon, whether in anterior, posterior, or lateral direction!

This will not be possible even after prior partial or total deflation of the balloon, nor after withdrawal of the balloon and reinsertion. The balloon will always be trapped in the same area in the scleral wall which will be the situation for several hours.

? But how long will you have to wait after withdrawal of the balloon before you can reinsert a balloon and obtain a different position of it?

? Hours? How many?

▶
- You have to wait for at least 18 hours; we have determined this exactly.
- With less elapsed time you will not succeed! These are the facts.

▶ **To have sufficient experience with the nondrainage procedure**

All of us have experienced that the localization of a detached break is not easy and requires practice. With the balloon operation the localization of a detached break is slightly more difficult.

- You will have to make the mark of the break on mobile conjunctiva and after insertion and inflation of the balloon catheter, you can no longer check the correct position of the balloon buckle by the conjunctival mark (as you could by the scleral mark with the sponge operation!).

The problem becomes even greater when there is only a flat balloon indentation discernible under a highly bullous detachment.

- Consequently, a **surgeon starting with the balloon operation should have experience with the non-drainage procedure.**
  Otherwise, he or she may not obtain the results a more experienced surgeon will obtain.

- Therefore, the following is true for the balloon operation:
  - **For the eye the balloon operation is *easy*.**
  - **But the technique is *difficult*.**
  - **However, with experience it becomes *easier*.**

Here are some suggestions on how to succeed when starting with the balloon procedure:

1. At the beginning, select a small detachment in which localization of the break with correct placement of the balloon will not be a problem.
2. Afterwards move step by step on to more extensive, then to more complicated detachments and to detachments with problems in viewing the retina.
3. Finally, to bullous detachments with a very posterior break or group of breaks of 1 clock hour in extent (see Chapter 9.6).

? If you follow these guidelines, you can be successful with the balloon operation and you will realize, it was worthwhile learning this procedure: Why?

- You can perform another and even more minimal extraocular procedure that needs only topical or parabulbar anesthesia and has even fewer accompanying complications.

– **The balloon procedure is an operation of short duration and you will have a satisfied patient.**

? Why?

▶ Because the visual acuity will have recovered completely within days or improved and no late deterioration of regained visual function will be expected.

9.6 Indications

● **The *balloon* buckle is suitable for retinal detachments caused by a *single break or a group of breaks* close together that do not subtend more than *1 clock hour or 6 mm* at the equator and are located in the anterior $^{2}/_{3}$ of the globe (**Fig. 9.**12**).**

As with segmental buckling, the extent of the detachment is not a factor in patient selection. When learning the balloon operation, start with a small detachment, in which neither the height nor the extent will present problems for localization of the break. There will be no significant parallax to jeopardize localization.

9.6.1 Small Detachment

You will recall that the original intention of the balloon procedure was to treat only small detachments in which a slightly detached break did not reattach after double patching and so was not suitable for laser treatment.

Here is the fundus of a patient (Fig. 9.**13 a**) who came with a detachment of 2 hours' extension and a horseshoe tear at 1 o'clock. The detachment was quite bullous. As part of our routine, the patient was double patched for 1 day and the next morning the detachment had substantially flattened and decreased in size. The break, however, was still detached and surrounded by a small detachment. Laser treatment would not be appropriate, additional buckling would be needed.

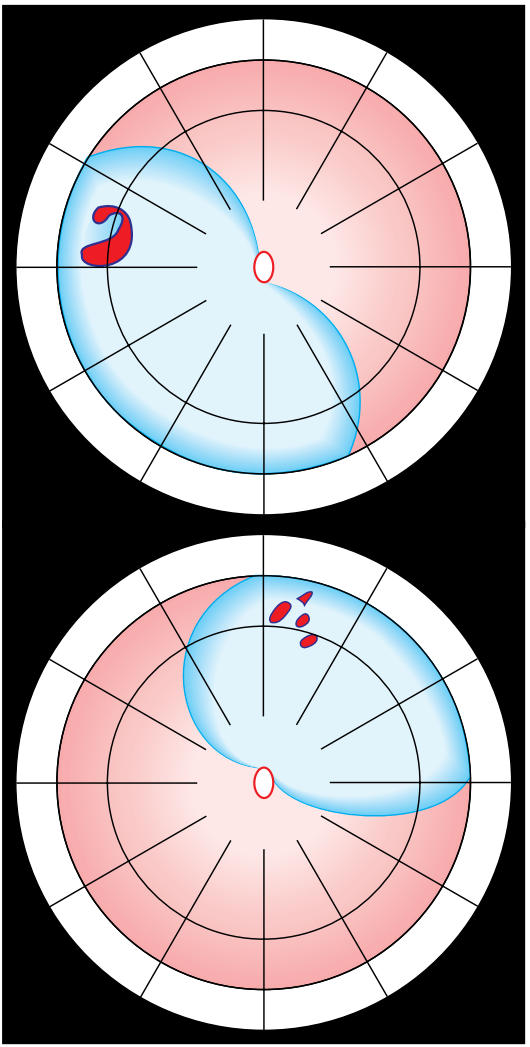


Fig. 9.**12** **Indication for the balloon operation:** A detachment caused by a single break (*Top*) or a group of breaks close together (*Bottom*) which do not subtend more than 1 clock hour or 6 mm at the equator and which can be located at any clock hour, i.e., superiorly and inferiorly, but which should be in the anterior $^{2}/_{3}$ of the globe.

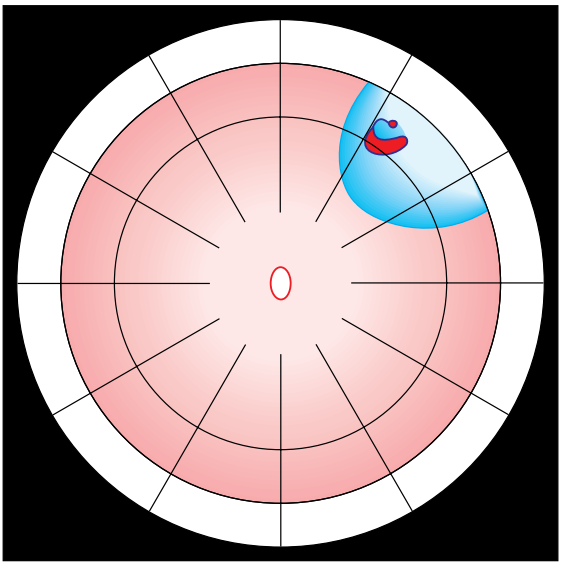


Fig. 9.**13 a** A small detachment (2 hours in extent) with a horseshoe tear at 1 o'clock.

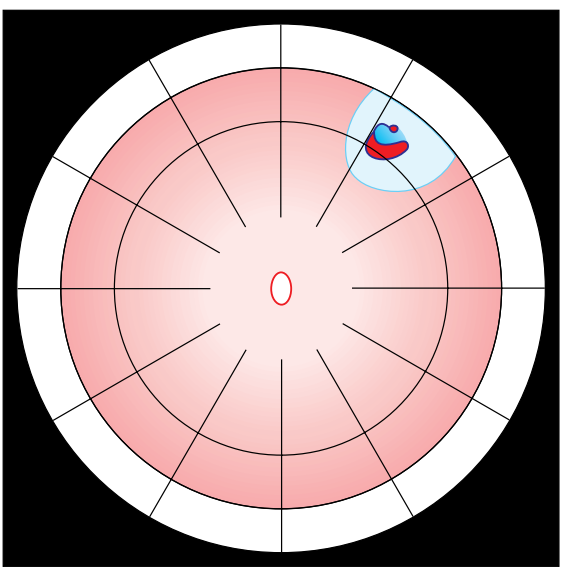


Fig. 9.**13 b** 1 day after double patching and lying the patient flat: The bullous quality of the detachment has disappeared, there is only a shallow detachment which has decreased in size. Such a small detachment is optimally suited for inserting your 1st balloon.

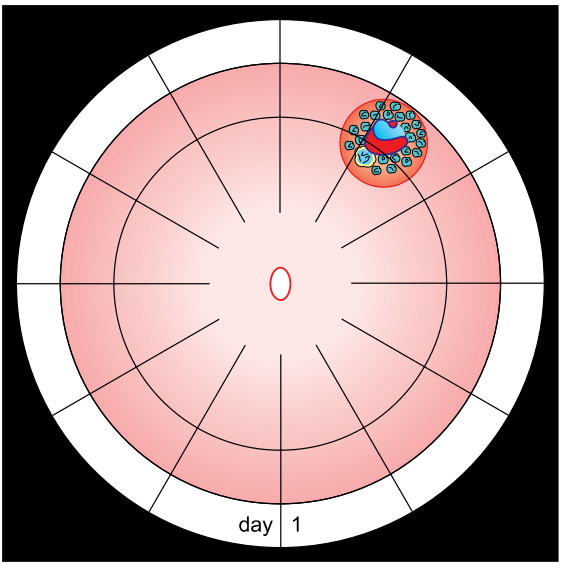


Fig. 9.**13 c** 1 day after balloon insertion in the detachment of Fig. 9.**13 b**: The horseshoe tear is stretched out on the balloon buckle, the localizing cryopexy mark is still exudative. Additional laser lesions were added to secure the tear.

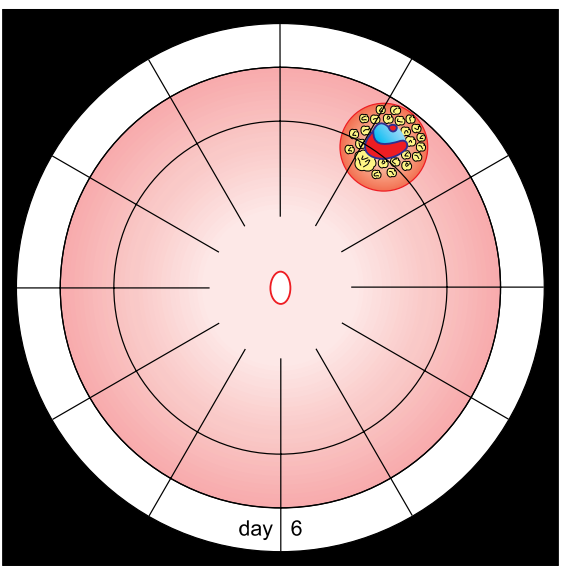


Fig. 9.**13 d** 6 days after balloon insertion: The horseshoe tear is sealed off by pigmented thermal lesions, ascertained by biomicroscopy.

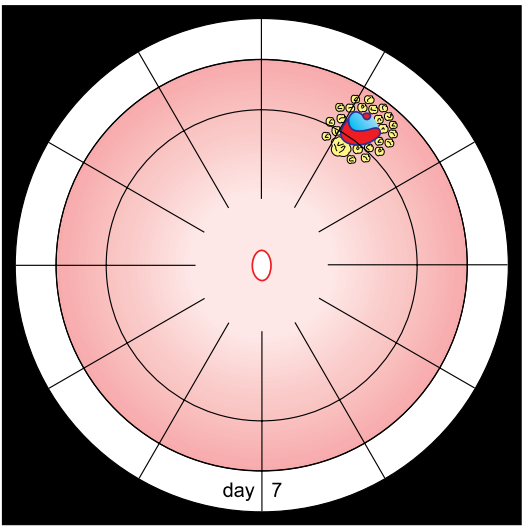


Fig. 9.**13 e** 7 days after balloon operation: The balloon has been deflated and the catheter withdrawn. The horseshoe tear has remained attached. Special care has been taken to seal off the operculum of the horseshoe tear towards the ora. Sustained attachment will solely depend on the adhesive strength of sufficient thermal lesions around the break.

But at this point let us recapitulate:

? Every detachment patient should be double patched for 1 day—or at least over night—prior to surgery. Why?

- In about 50% of detachments the retina will flatten, providing easier localization of the break during surgery.
- In a small percentage the contour of detachments will change.
- In some detachments reattachment of the break might occur and, as a result, laser treatment become feasible.

Assuming you are performing your first balloon procedure and you have selected a small detachment with a horseshoe tear (Fig. 9.**13b**),

localization of such a tear will not be a problem, even if your localization technique is not yet perfect.

The inserted balloon has provided sufficient tamponade of the tear and the next morning the retina will be reattached (Fig. 9.**13c**). Since only 1 localizing freezing mark has been placed (at the posterior edge of the tear), the remainder of the circumference of the reattached tear has to be sealed off with additional laser applications. Of course you could have surrounded it with transconjunctival cryopexy intraoperatively.

Prior to removal of the balloon you have to confirm with biomicroscopy that the tear is sufficiently surrounded by thermal lesions (Fig. 9.**13d**). After 1 week the balloon is removed in 2 steps (Fig. 9.**13e**). Details of this procedure have already been given above (see Chapter 9.4).

? What did you learn after your 1st balloon procedure?

- A parabulbar balloon, not being fixed by sutures, can provide a **reliable buckle** during the entire period required for a retinal adhesion to form.
- If the balloon is positioned correctly under the break and no break was overlooked, **subretinal fluid will disappear** as quickly as you have already experienced with the nondrainage procedure when using sewn on elastic explants.

However, the balloon procedure offers another advantage. If the morning after the operation you should find out that the buckle is not large enough, without any surgical intervention you can enlarge the diameter of the balloon buckle by another 2 to 4 mm just by injecting additional fluid through the valve fixed at the patient's forehead. Inject 0.5 ml at a time and be certain to check the central artery for patency.

Therefore:
In comparison to a sponge buckle sewn on to sclera, **the balloon has the advantage that it can be enlarged postoperatively without additional surgery,** i.e., by injecting up to 1.0 ml of fluid (Fig. 9.**14**) in steps (check patency of central artery!).

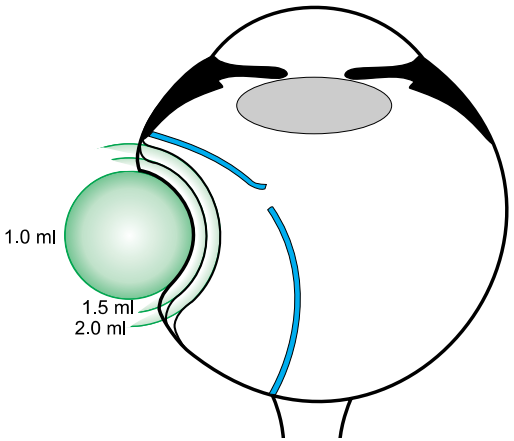


Fig. 9.**14** **Options to enlarge the balloon indentation:** By injecting up to 1 ml of additional fluid (in 2 steps) you can raise and enlarge the balloon indentation. In the diagram you see the indentation induced by a balloon filled with 1 ml of fluid (the posteriorly located horseshoe tear is not yet reattached). By injecting another 0.5 to 1.0 ml of fluid (check central artery for pulsation!) the balloon will become enlarged and thus suffice to reattach the horseshoe tear in this bullous detachment.

Having become familiar with the technique of the balloon operation and after your 1st, hopefully, successful procedure, you should feel confident enough to move on to more difficult detachments.

9.6.2 2-Quadrant Detachment

Somehow this detachment will challenge your diagnostic techniques (Fig. 9.**15a**):

? Why?

- You have to be sure not to overlook an additional break in the more extensive detachment.
- There may be an area of "suspicious" lattice degeneration. Now you might recall:
  A round "hole" within lattice degeneration is rarely a full-thickness hole
  and does not require treatment.

- The detached hole at 1:15 is smaller than the one in the previous detachment. It will be more difficult to find it at the operating table, but be sure to avoid excessive freezing and depression.
- The hole at 1:15 is more elevated because it is more posterior. However, the parallax when localizing should not be too difficult for you.

The break is located at 15 mm from the limbus, the balloon catheter is inserted to the pre-determined position and inflated with 0.75 ml

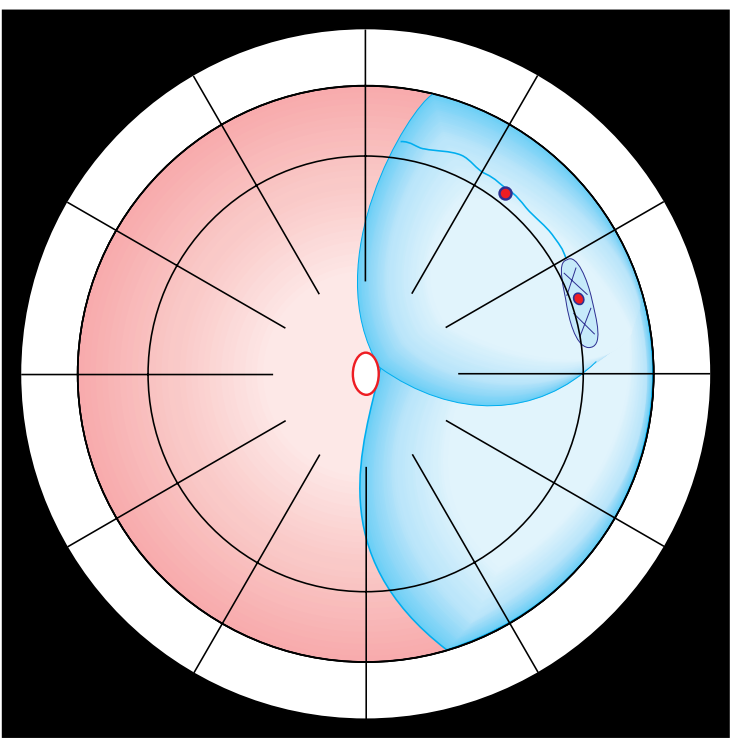


Fig. 9.**15 a** A 2-quadrant detachment: A so-called anterior traction line extends from 12:15 to 2 o'clock with a round hole at 1:15. The adjoining lattice degeneration has a pseudohole (lamellar hole).

of fluid. Since the hole is still elevated above the shallow balloon buckle (not yet having reached its full indentation), you decide to be on the safe side, to inflate the balloon some more, i.e., to a total of 1.0 ml of fluid. Again, do not forget to check the central artery for pulsation after the additional inflation.

? Will you have to treat the adjacent lattice degeneration?

▶ No.

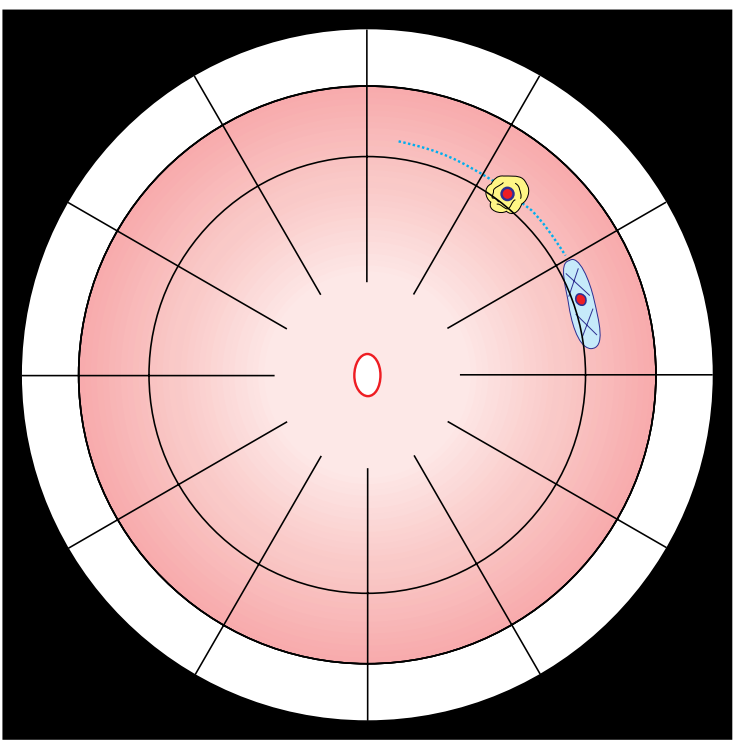


Fig. 9.**15 b** The balloon buckle was placed under the round hole at 1:15, the hole became surrounded with transconjunctival cryopexy and the retina reattached. The balloon catheter was withdrawn after 7 days, the retina remained attached. The lattice degeneration was not treated. During the next days the anterior so-called traction line disappeared.

? Or postoperatively as a prophylactic measure?

▶ **No.** Let me explain:

Even after reattachment, the lattice degeneration does not require prophylactic treatment, even when presenting with pseudoholes (partial thickness or lamellar holes).

? But what would we do instead of an *"active" prophylaxis* (i.e., cryopexy or laser)?

▶ We would explain to the patient the symptoms of a detachment and how to test the visual field on a regular basis.
As you will recall, we define this as ***"passive" prophylaxis*** because it does not imply surgical treatment (see Part 1, Chapter 6.3, pp. 90–92).

The next morning the retina is reattached. The break has been surrounded sufficiently with cryopexy at surgery. After 1 week the lesions are pigmented, the balloon is removed, and the retina remained attached (Fig. 9.**15b**).

9.6.3 3-Quadrant Detachment

This detachment (Fig. 9.**16a**) represents another degree of difficulty.

? Why?

▶ **Let me define the additional problems you will be confronted with when treating this detachment:**
- This detachment is more extensive; more holes can be overlooked.
- It is more bullous; more parallactic displacement when localizing the detached break.
- The tear is larger, i.e., easier to find; but there is less leeway when positioning an adequate buckle beneath it.

As a consequence, your balloon buckle has to be centered precisely beneath the tear.

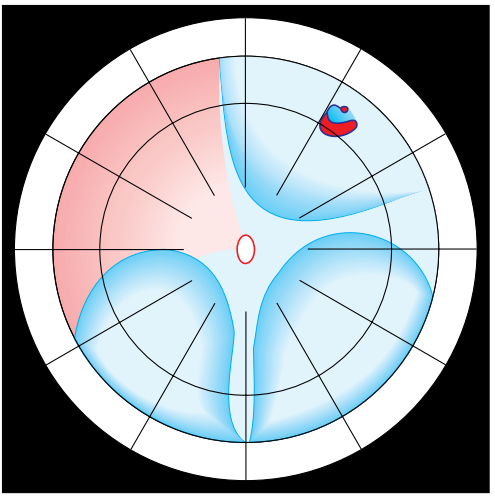


Fig. 9.**16 a** A bullous 3-quadrant detachment with a horseshoe tear at 1 o'clock.

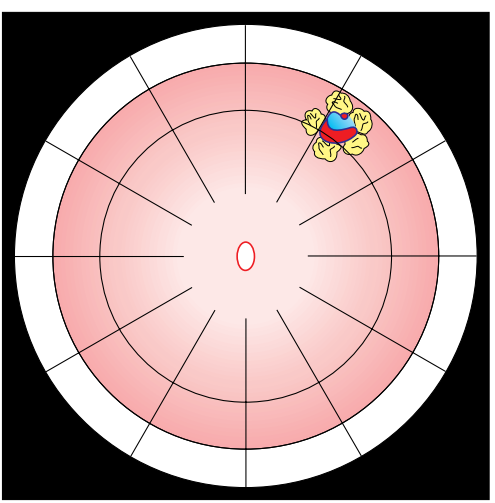


Fig. 9.**16 b** The balloon was placed beneath the horseshoe tear and the retina reattached. The tear had been surrounded with cryopexy lesions. After 7 days the balloon was withdrawn, the retina remained attached.

? What might also cross your mind when looking at this 3-quadrant detachment?

▶ Let us pause for a moment:
- This more extensive detachment could represent the same eye we have already seen in Figure 9.**13**, but a few days later because the detachment has acquired a larger extent.

Now concerning treatment: After insertion of a balloon under the tear and inflation with 1.0 ml of fluid, the tear, which was still detached at the operating table, has reattached the next morning and all of the subretinal fluid has disappeared (Fig. 9.**16b**). Additional laser treatment around the tear is not needed because it was surrounded with transconjunctival cryopexy.

? What did you learn from this detachment?

▶
- A break still detached on top of a balloon buckle at surgery will be reattached the next day if the balloon is localized correctly, i.e., providing an adequate tamponade.
- **The extent of a detachment is not a limiting factor when applying the balloon procedure.**

9.6.4 Total Detachment in a Pseudophakic Eye

This total detachment in a pseudophake with some precipitates at the intraocular lens and a minor secondary cataract will represent another challenge for you (Fig. 9.**17a**), because you do not want to perform a "prophylactic" encircling operation due to uncertainties in the periphery [22] or a primary vitrectomy with a preceding removal of the opacities in the anterior segment and a gas tamponade.

? But what are the problems when doing, instead, a balloon procedure?

▶
- You have to be certain that you did not overlook an additional break in this detachment because it is more extensive than the previous detachments.

- It is crucial to exclude the presence of an additional tear, especially at the lateral borders of the lattice degeneration.
  Remember: "Hole" formations or "erosions" within lattice degeneration are probably pseudoholes.
- The hole you have detected at 11:30 in this detachment is very tiny; however, its location fits Rule 2 of how to find the primary break and therefore it alone can cause this total detachment (see Part 1, Chapter 2.2, pp. 13-18).
- Due to the presence of opacities in the optic media you have to be certain of finding this break also at surgery, therefore you should plan prospectively to plot it quickly and precisely.

? What should be done to find at surgery a tiny break in the presence of opacities in the optic media?

▶ **The following measures can be taken 1 day prior to surgery:**

- You should make a precise fundus drawing depicting retinal features in the vicinity of the break (e.g., vessels, pigment spots).
- You should estimate the distance of the break either in disk diameters from the ora serrata or, after gaining more experience, in millimeters from the limbus.
- Perhaps, in addition, you might mark the radian of this tiny break with a laser spot in the pars plana.

The detachment is bullous and it did not flatten substantially after double patching overnight. However, since the break is located quite anteriorly, there will not be much parallactic displacement and intraoperatively you will circumvent the opacities within the optic media with your *"day before surgery preparations"*.

At the operating table, the plotting of the break went smoothly and the break was treated with cryopexy. The balloon buckle, inflated with 0.75 ml of fluid, could be viewed in relation to the tiny hole. Postoperatively the patient was double patched.

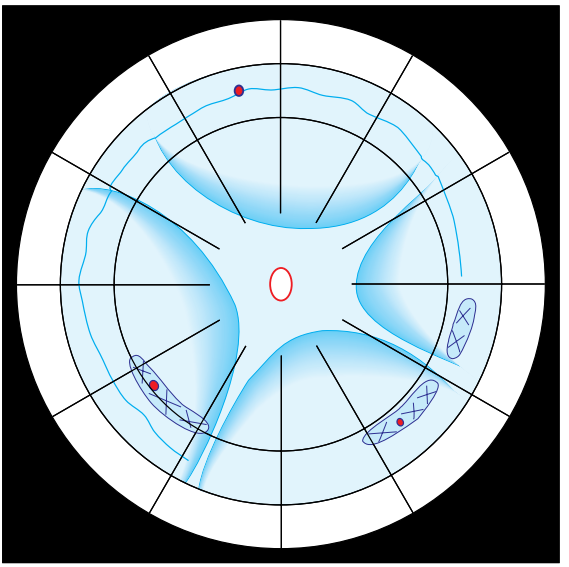


Fig. 9.**17 a** A total bullous detachment in a pseudophakic eye: There is a tiny round hole at 11:30 in an anterior so-called traction line. Within the inferior lattice degenerations are only pseudoholes.

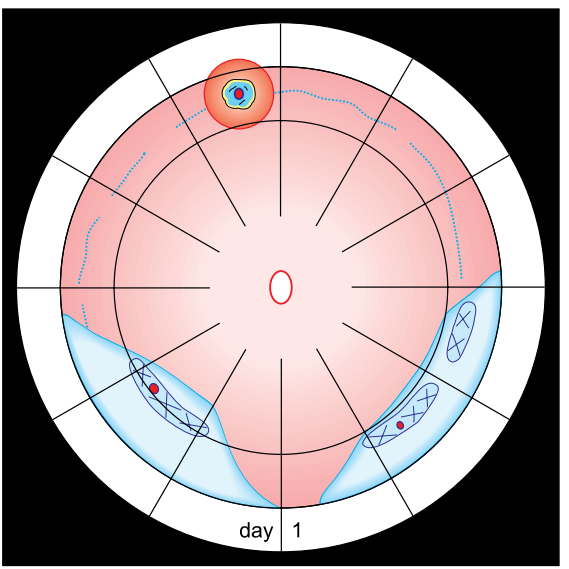


Fig. 9.**17 b** 1 day after balloon operation: The hole is surrounded by exudative cryopexy and tamponaded by the balloon buckle. The retina has reattached except for residual fluid around the inferior lattice degenerations.

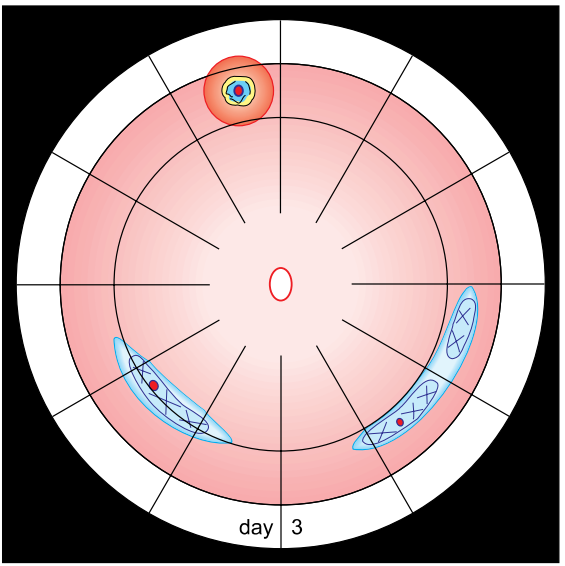


Fig. 9.**17 c** 3 days after balloon operation: The residual fluid has almost completely disappeared and is limited to the area of the lattice degenerations.

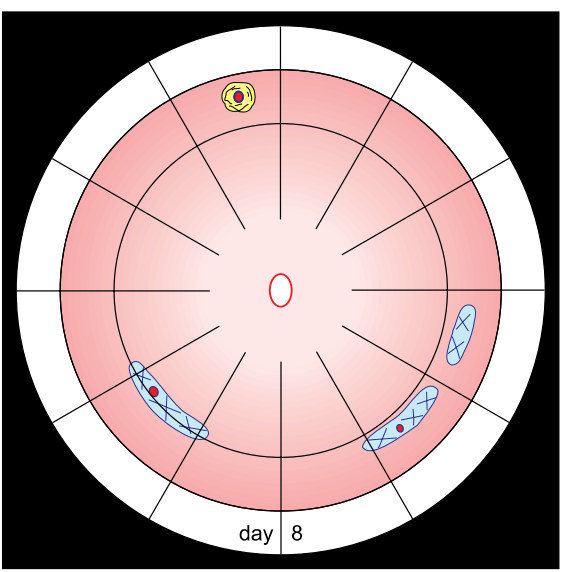


Fig. 9.**17 d** 8 days after balloon operation: The round hole is surrounded with a pigmented cryopexy lesion, the balloon is withdrawn, the retina remains attached, the residual fluid around the lattice degenerations has disappeared. The lattice degenerations were not sealed off with prophylactic laser lesions.

Special positioning was not required because you were convinced that there was only 1 break to be treated and that the balloon was placed correctly beneath it.

The next morning the retina was reattached (Fig. 9.**17b**), except for a residual detachment around the areas of inferior lattice degenerations (see Part 1, Chapter 8.13, pp. 212–224).

? — **What to do now?**
— **Did you perhaps overlook another break?**
— **Should you double patch and lie the patient flat?**
— **Or will you perform a reoperation?**

▶ **None** of these propositions, since the retina had reattached postoperatively except for some residual fluid inferiorly.

? **What will you do instead?**

▶ — You will **mobilize the patient** and ask him or her
— **To sleep with the head elevated.**

? **Why?**

▶ To prevent pooling of residual fluid into the macula overnight.

There was less residual fluid on the 3rd day and the retina was reattached completely on the 8th day (Figs. 9.**17c, d**). The patient has a follow-up of $7^1/_2$ years, so far without redetachment, in spite of not having treated the inferior multiple areas of lattice degenerations. However, the patient was instructed about how to perform "passive" prophylaxis on a regular basis.

9.6.5 Detachment with a Break beneath a Muscle

A detachment patient with a retinal break or breaks located beneath a rectus muscle that are treated with a sponge explant (particularly a radial one) can be prone to postoperative diplopia [23]. In such a patient (Fig. 9.**18a**)—under the proviso that there is

only 1 break or a group of breaks within 1 clock hour—the balloon procedure is especially indicated.

? Why?

▶ Because the balloon buckle, unlike a scleral sponge, does not cause permanent muscle imbalance.

As long as the balloon is in place, there is diplopia. However, within hours of the balloon being deflated and removed, the diplopia regresses and the muscles function normally again.

? But how will you position the balloon buckle in the meridian of a rectus muscle?

▶ **Here is how to proceed:**
- **For an anterior break,** incise the conjunctiva over the tendon, separate the tendon fibers by 2 mm, and insert the balloon catheter through the tendon beneath the muscle.

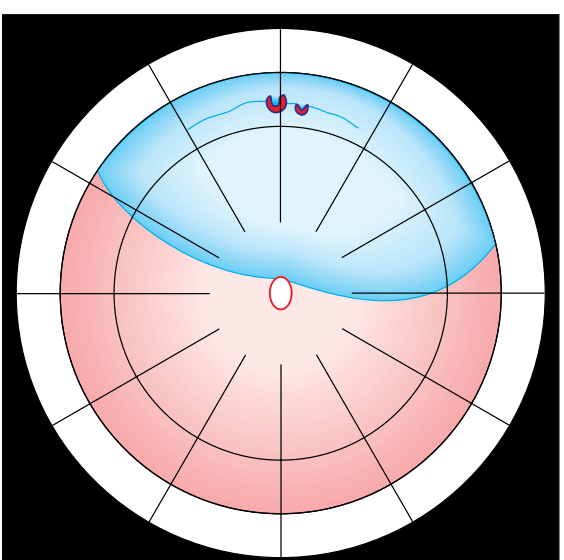


Fig. 9.**18 a** A superior detachment with 2 breaks beneath the superior rectus muscle in an aphakic eye with an anterior so-called traction line.

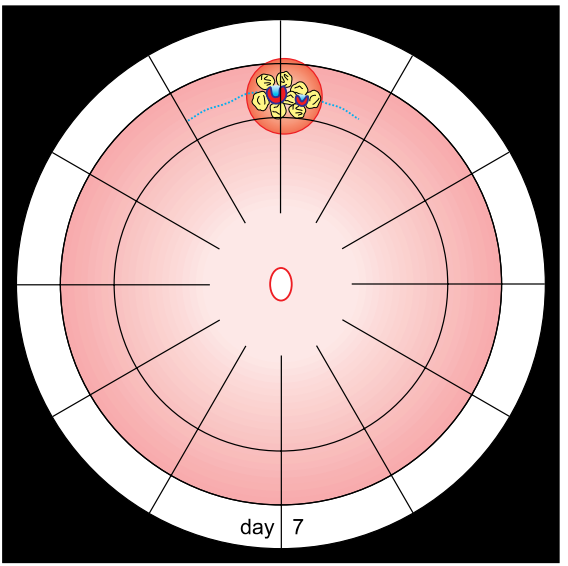


Fig. 9.**18 b** 7 days after balloon operation: The 2 breaks are sufficiently secured with pigmented cryopexy lesions, as ascertained by biomicroscopy. The retina has reattached. With the balloon in place the patient still has diplopia.

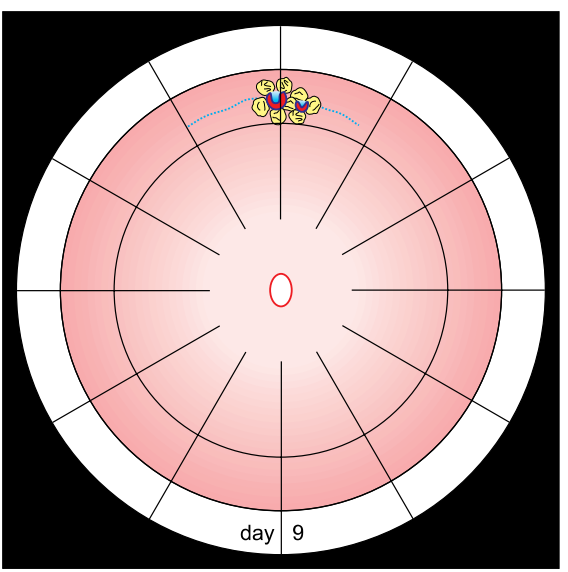


Fig. 9.**18 c** 9 days after balloon operation: The balloon was withdrawn the day before, the retina has remained attached. The patient no longer has diplopia since the temporary balloon buckle has been removed.

- **For a more posterior break,** insert the catheter at the pre-calculated distance from the limbus, maneuver the catheter beneath the Tenon's capsule, independent of whether it will be located on top of or beneath the muscle, and inflate the balloon.

At this moment you should recall that the pressure of the balloon on the underlying tissues will decrease within minutes and after 1 to 2 hours to the level of normal intraocular pressure. The balloon will remain in this area for 1 week only (Figs. 9.**18b, c**).

? Diplopia will disappear within hours of removing the balloon (Figs. 9.**19a, b**): **How often did this happen in a larger series of patients?**

▶ A balloon was inserted in the area of a rectus muscle in 184 detachment eyes without causing postoperative permanent diplopia in a single patient after withdrawal of the balloon [24–26].

9.6.6 Old Detachment

The duration of a detachment—as already accepted in the non-drainage operation with sponges (see Part 1, Chapter 8.6, pp. 144–163)—is as well not a contraindication for using a temporary balloon buckle. As we have experienced and agreed upon meanwhile, old subretinal fluid will absorb as quickly as recent fluid when the retinal break is closed; this is also valid for the balloon buckle.

To recapitulate:

? What are the characteristics that testify for a detachment of long duration?

▶ 1. Pigment demarcation line(s) beneath and/or at the border of the detachment.
2. Thin atrophic and transparent retina.
3. Cyst(s) in the retina.
4. Glial lines beneath the retina.
5. Sometimes precipitates at the outer surface of the detached retina.

Fig. 9.**19** Detachment patient treated with a parabulbar balloon (Photo courtesy of H. Lincoff, M.D.); *Left:* With a parabulbar balloon in the area of the rectus muscle, tamponading a horseshoe tear at 9 o'clock; ocular rotations are limited. *Right:* Within hours after withdrawal of the balloon, the diplopia has disappeared. The eye muscles function normally again.

In a detachment with these findings (Fig. 9.**20a**) we would not hesitate to insert a balloon beneath the break, even if the break is located inferiorly.

? Why?

You will recollect that delayed absorption of subretinal fluid is not due to the age of the detachment, nor the age of the patient, but due to an *atrophic pigment epithelium and choriocapillaris.*

This finding can be present in some elderly patients, but also in younger patients, e.g., in high myopes.

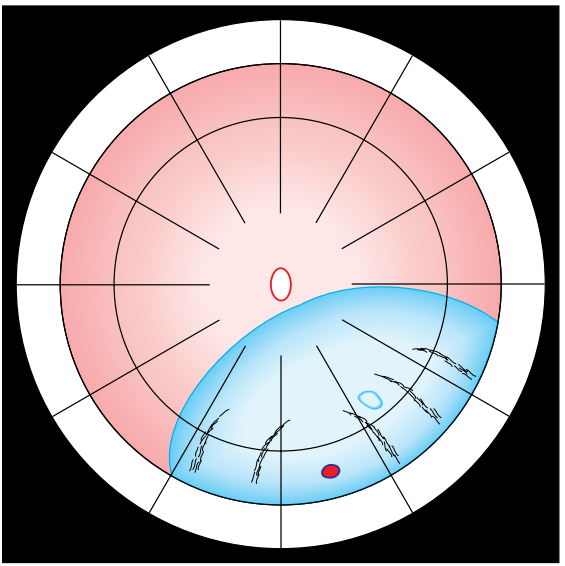


Fig. 9.**20 a** An old inferior detachment with several pigment demarcation lines, an intraretinal cyst and a round hole at 5:30.

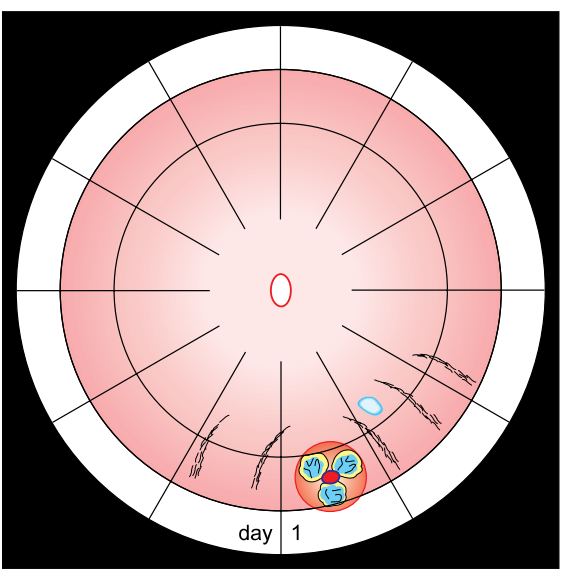


Fig. 9.**20 b** 1 day after balloon insertion: The retina has reattached, the pigment demarcation lines have become more prominent and the hole is surrounded by exudative cryopexy lesions. The Intraretinal cyst is still visible.

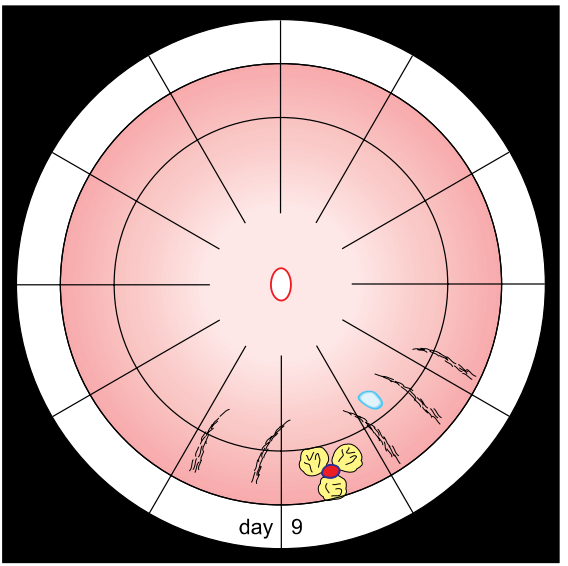


Fig. 9.**20 c** 9 days after balloon operation: The cryopexy lesions have pigmented and the balloon is withdrawn in 2 steps after 8 days.

? Why does even a detachment with an expected delayed absorption imply a special indication for the balloon buckle?

▶ Because if there is delayed reattachment of an inferior break, the next morning you can easily raise the buckle by injecting additional fluid.
— And that is all that has to be done.

If the hole is positioned adequately above the balloon buckle, it will reattach (Figs. 9.**20b, c**). If its reattachment is delayed for several days, then the hole has to be secured by additional laser lesions.

Experience with another type of balloon, the therapeutic balloon, shows that a parabulbar balloon can be left in place for several weeks, if needed. The therapeutic balloon is withdrawn after 7 weeks [27].

9.6.7 As Diagnostic Probe to Detect the Break or to Exclude the Presence of Another Break: Examples 1 to 6

An indication for the parabulbar balloon is to test an area of suspicion in a detachment in which no break could be found. The balloon is used to probe this area [28]. Reasons for not finding the break preoperatively could be: Either a tiny break (difficult to detect), a small pupil, or hazy media.

? But what are the advantages of a successful diagnostic balloon?

▶ It eliminates the need for:
- A prospective larger procedure, such as a cerclage and extensive coagulation.
- Or a primary vitrectomy, which could be considered but would incur an increased morbidity.

Here are some examples in which a diagnostic balloon can be applied:

▶ Example 1: A total pseudophakic detachment with capsular remnants

In this total detachment (Fig. 9.**21a**) the visualization of the anterior retina is limited by an intraocular lens and capsular remnants. No break could be found, however, there was a circular, so-called traction line with a suspicious tit at 11:30. To detect this area intraoperatively, a laser mark was placed in the pars plana (possible by depression) in the radian of the tit. The lattice degeneration between 1 and 2 o'clock had only a pseudohole. Of course, the borders of the lattice degeneration could harbor a tear, but no suspicious area could be detected.

Intraoperatively the traction line was probed for a break and diagnostic freezing was applied to the tit at 11:30 without confirming a break. Since this was still the only area of suspicion, a parabulbar balloon was inserted beneath the cryopexied area. The lattice degeneration was not treated. The next morning the retina was reattached and the entire buckle—because it had to harbor the invisible break which was now tamponaded by the balloon—was secured with interrupted laser lesions (Fig. 9.**21b**). The balloon was withdrawn after 1 week, the retina remained attached (Fig. 9.**21c**).

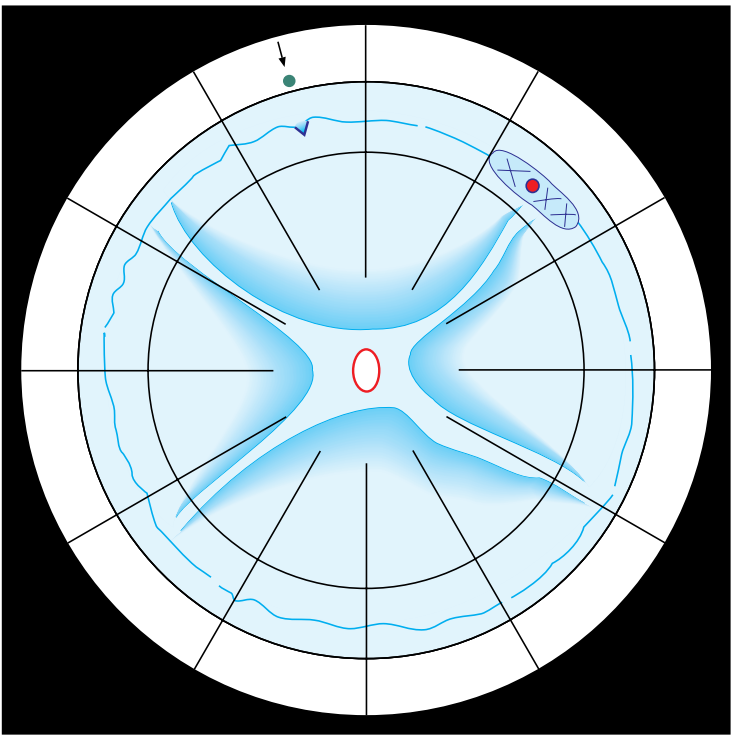


Fig. 9.**21 a** A total pseudophakic detachment with capsular remnants and no hole found: In the anterior “traction line” at 11:30 a little tit was discovered, which was difficult to visualize through the capsular remnants. To detect this area at the operating table, in the radian of the tit a laser mark was placed in the pars plana (possible by depression of this area).

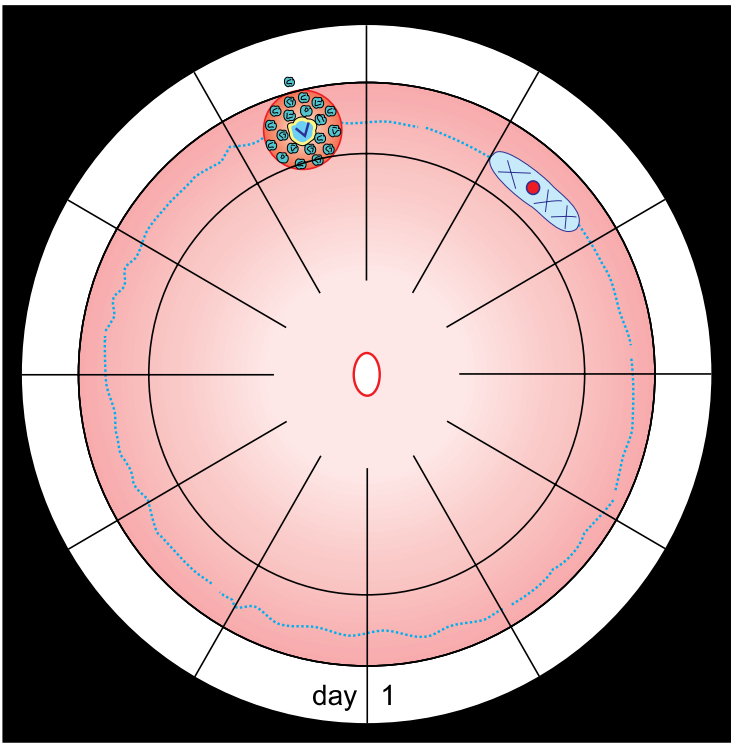


Fig. 9.**21 b** 1 day after balloon operation: A balloon was inserted beneath the tit at 11:30. The localizing cryopexy lesion is visible on the balloon buckle. The retina is reattached. Since the break was not found for certain, it had, however, to be located in the area of the balloon buckle. Therefore the entire buckle was secured with interrupted laser lesions. The lattice degeneration with a pseudohole was not treated.

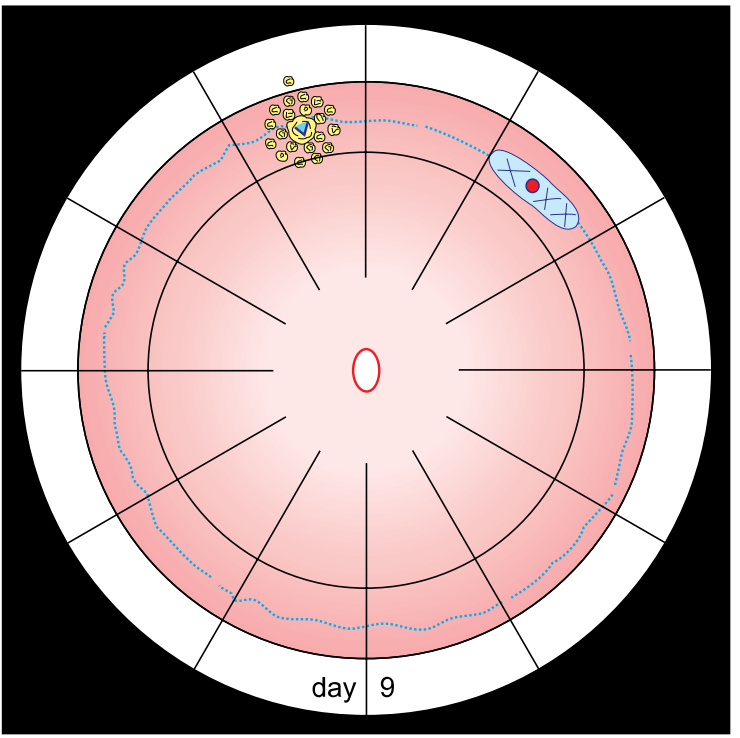


Fig. 9.**21 c** 9 days after balloon operation: The balloon was withdrawn, and the entire area of suspicion, formerly placed on the buckle, was covered with pigmented thermal lesions. The retina remained attached. The lattice degeneration was not treated, not even at a later time.

▶ **Example 2: A detachment in presence of a vitreous hemorrhage**
This patient came to us with a so-called "vitreous hemorrhage"—which, luckily for the patient—was in part confined to the retrohyaloidal space (see Part 1, Chapter 3, pp. 27–40). After double patching for 1 day with elevation of the patient's head, the retrohyaloidal blood had settled, and a detached tear at 10 o'clock could be found (Fig. 9.**22a**). The borders of the detachment, extending from 2:30 over 6 to 11 o'clock, could be determined. However, due to the re-

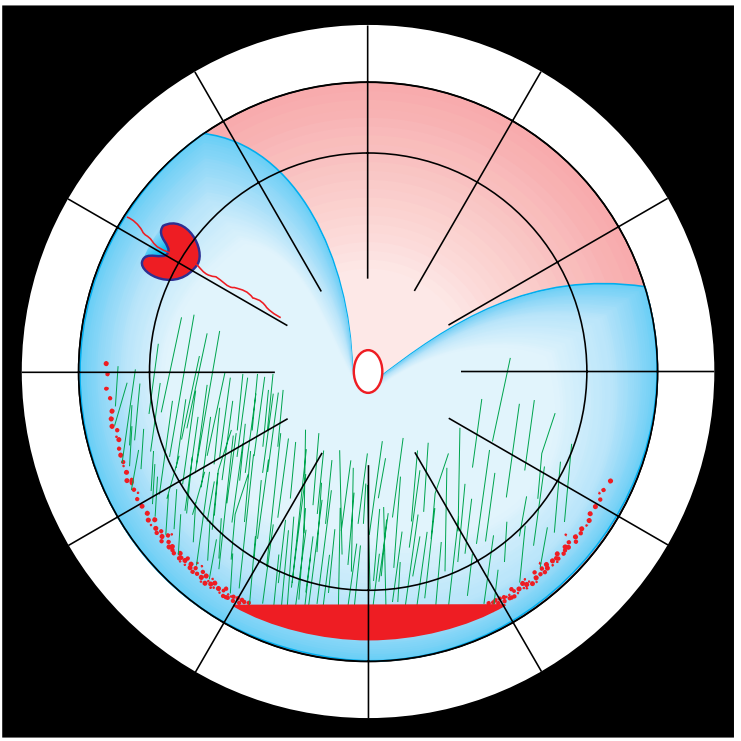


Fig. 9.**22 a** A detachment in the presence of a vitreous hemorrhage: After double patching and elevation of the patient's head for 30° overnight, the borders of the detachment could be defined and a horseshoe tear at 10 o'clock localized. However, the area between 5 and 8 o'clock could not be visualized to exclude an additional break.

sidual hemorrhage within the vitreous, the entire retina could not be visualized to exclude another more inferior break. Yet the tear at 10 o'clock could have caused this type of detachment.

Consequently, a diagnostic parabulbar balloon was inserted beneath the tear at 10 o'clock, which was surrounded with cryopexy. An additional cryopexy lesion was placed posteriorly at the tear in the area of the vessel.

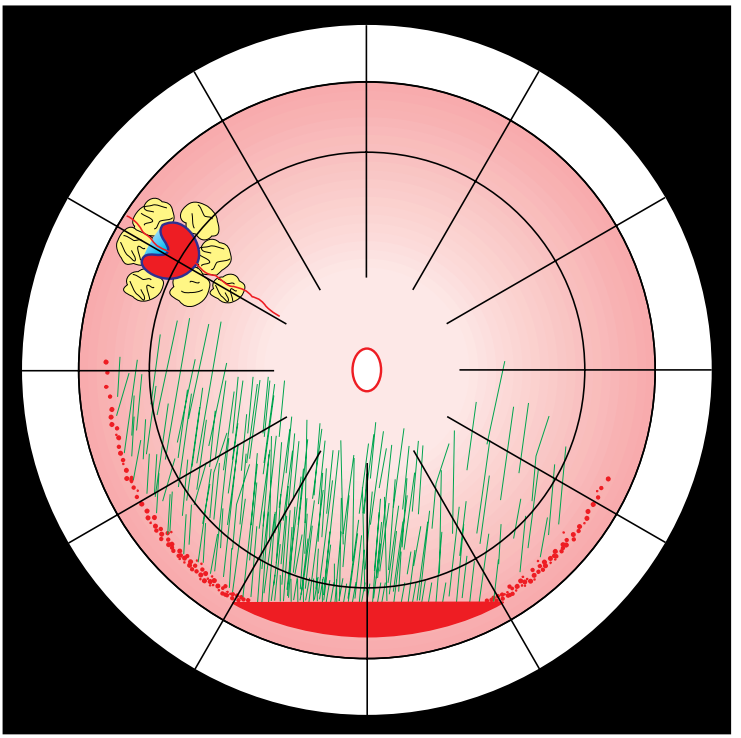


Fig. 9.**22 b** A diagnostic balloon was inserted beneath the horseshoe tear, and the retina reattached completely (ascertained by ultrasonography). An additional cryopexy lesion was placed posterior to the tear in the area of the vessel. This was done to counteract future leakage of the posterior edge of the tear due to vitreous traction, that might be exerted upon this vessel since being in communication with the tear. The balloon was withdrawn after 1 week, the retina remained attached.

? Why?

▶ Because sometimes redetachment originates from such a vessel, communicating with the tear, when vitreous traction is exerted upon it.

The next morning the entire retina was reattached, which was confirmed by ultrasonography (Fig. 9.**22b**). Since the view to the infe-

rior retina was still obscured, the patient was advised to test the visual field (being circular, but tinted red) on a regular basis and to watch for a descending shadow. No redetachment occurred during the period of vitreous clearing, nor during the subsequent 5 years.

Example 3: A bullous detachment with a posterior tear in close proximity to a vertical muscle and an additional, but questionable tear

This very bullous detachment extending from 9 over 12 to 3 o'clock has a tear posterior to the equator at 11 o'clock at the lateral edge of extensive lattice degeneration (the most likely area of tearing). An additional tear at the opposite edge of the lattice at 2:15 could not be excluded preoperatively (Fig. 9.**23a**).

Consequently, as first minimal approach, a diagnostic parabulbar balloon was inserted beneath the obvious tear at 11 o'clock.

? The balloon was selected for the following reasons:

- To avoid diplopia, which would have resulted if, as an alternative, a large buckle had been fixed in the area of the superior rectus muscle.
- To exclude the presence of a second, but questionable break at 2:15. This would be confirmed if the retina reattached after buckling the break at 11 o'clock.
- Even, if application of the diagnostic balloon had not resulted in complete reattachment, at least the balloon buckle would have somehow reduced the bullous quality of the detachment, facilitating localization of the posterior tear at subsequent surgery.
- **However, you should only operate upon a bullous detachment with such a posteriorly located tear, if you have sufficient experience with the balloon procedure.**

With a diagnostic freeze, at the opposite edge of the lattice degeneration, a tear at 2:15 could be excluded and the horseshoe tear at 11 o'clock was marked on conjunctiva 19 mm from the limbus. The balloon was then inserted beneath the tear and inflated with 1.3 ml of fluid. This large volume was achieved in 2 steps after ascertaining pulsation of the central retinal artery. The next morning all of the subretinal fluid had disappeared and the retina was re-

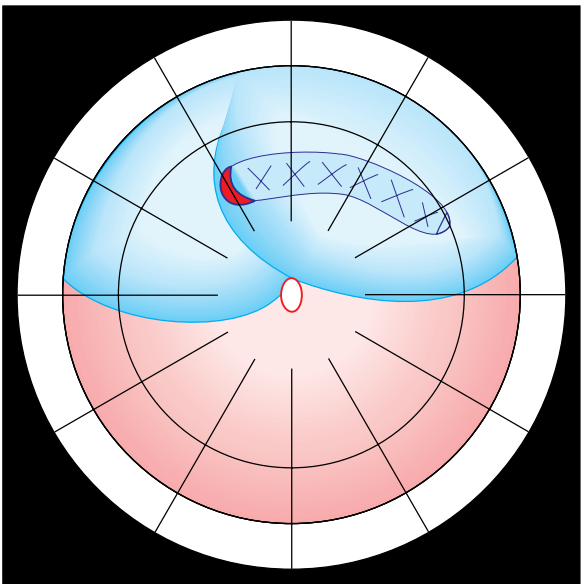


Fig. 9.**23 a**

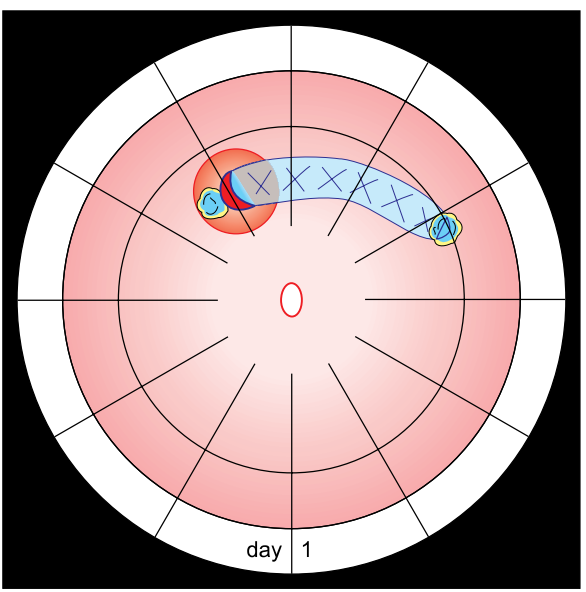


Fig. 9.**23 b**

Fig. 9.**23 c**

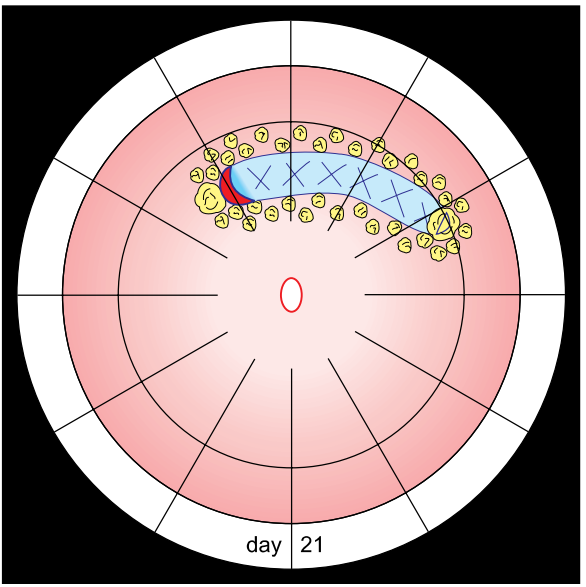


Fig. 9.**23 a** A bullous detachment with a posterior horseshoe tear at 11 o'clock at one lateral edge of extensive lattice degeneration and a doubtful tear at the opposite edge: To avoid diplopia due to a large buckle in the area of the superior rectus muscle or complications accompanying a primary vitrectomy with a gas injection, a diagnostic balloon was, instead, inserted beneath the horseshoe tear at 11 o'clock, 19 mm from the limbus. **b** 1 day after insertion of the diagnostic balloon: The retina had reattached, the localizing cryopexy mark at the horseshoe tear is visible as well as the diagnostic freeze, confirming that there was no additional break at 2:15. **c** 21 days after balloon operation: The horseshoe tear and the lattice degeneration were surrounded by pigmented cryopexy and laser lesions. (Today we would be hesitant to surround the entire lattice degeneration with prophylactic laser lesions). No further treatment was needed in the subsequent 7 years.

attached (Fig. 9.**23b**). Only the lateral edge of the horseshoe tear at 11 o'clock was treated with 1 cryopexy lesion (localizing mark) due to the uncertainty of subsequent reattachment. Additional laser lesions were then added to secure the tear and the adjacent lattice degeneration (Fig. 9.**23c**). Admittedly, today we would be hesitant to treat such an extensive lattice degeneration in addition with prophylactic laser lesions.

? Why?

- In this situation the prophylaxis would have a very large extent.
- Instead we would inform the patient about the symptoms of a detachment and the testing of the visual field on a regular basis, to make sure that the patient would come in time for treatment, if needed.
  In other words, we would administer "passive" prophylaxis (see Part 1, Chapter 6, pp. 90–92).
- **On the contrary, we have made the following observation:**
  An extensive, let us call it "active" prophylaxis, leads the patient to believe, unjustifiably, that he or she will be cured.
- And this is exactly what you do not want.

? Why?

Because it would result in diminished alertness on the part of the patient to perceive early symptoms of a detachment, in other words, you would risk the mandatory compliance to watch out for these symptoms and to test the visual field on a regular basis.

? Why is this so important?

To be certain that the patient will come in time for treatment.

Now another examination you should do postoperatively: Even if the retina is reattached, you should check the state of the posterior vitreous membrane to see whether it is completely detached.

? Why?

- In a situation where the vitreous membrane is not completely detached, you should examine this patient on a more regular basis.
- In addition, you should examine the state of the posterior vitreous membrane in the fellow eye.

? Why?

- If the vitreous in the fellow eye is not yet detached, the chances of developing a break or detachment might range between 20% and 35%.
- If, however, the posterior vitreous membrane is already completely detached, the chance of a retinal detachment is less than 10%.

Example 4: Two separate detachments

This patient is another challenge for you. There are 2 separate detachments: The superior one extends from 8:30 to 12:15 and the inferior one from 6:15 to 8:15 (Fig. 9.**24a**). No connection between the 2 detachments can be detected. Therefore it was assumed that there were 2 separate detachments and you would have to find a break in each.

After an extensive search of the superior detachment a questionable hole at 11 o'clock was found at the edge of a lattice degeneration with apparent vitreous traction. Within the lattice degeneration at 12 o'clock was a hole that was probably a partial thickness or lamellar hole.

? First consider the questionable hole at 11 o'clock in the superior detachment. What do you detect?

Posterior to the questionable "hole" there is a pigment demarcation line within the detachment.

? What does this imply?

- The convexity of this demarcation line actually points to the area of the hole, since it defines the former extent of a detachment of some duration around it.
- **Consequently, the questionable hole at 11 o'clock is most likely the cause of the superior detachment and not the "hole" within the lattice degeneration at 12 o'clock.**

The pigment demarcation line indicates that the superior detachment had enlarged in posterior, inferior, and to a lesser extent in superior direction.

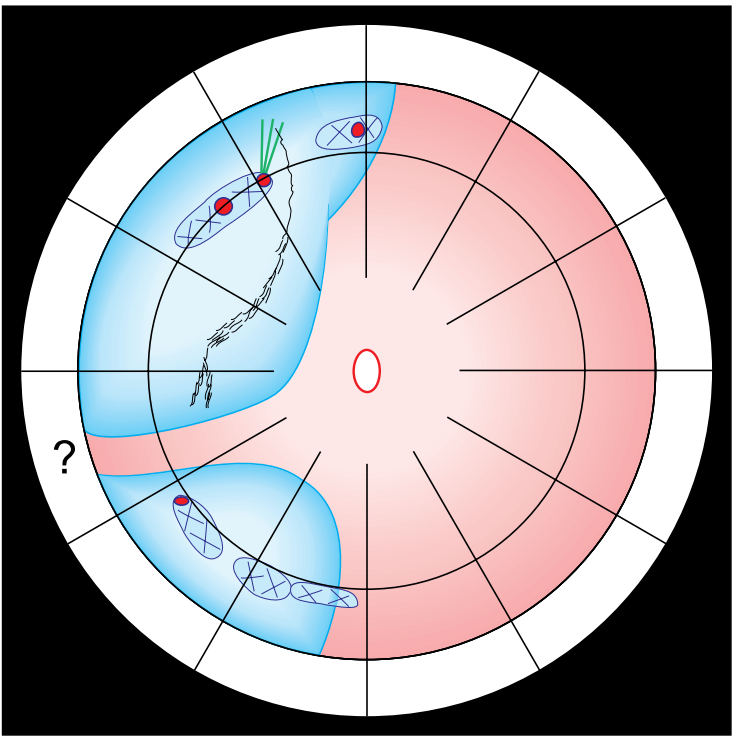


Fig. 9.**24 a** 2 separate detachments: There is a superior detachment with 2 lattice degenerations and “erosions”. A most likely break is located at 11 o’clock with obvious vitreous traction at the lateral edge of lattice degeneration. Note the convex pigment demarcation line beneath the superior detachment posterior to the lattice degeneration, indicating that a full-thickness break might be present at 11 o’clock. In the inferior detachment there is a questionable tear at 8 o’clock at the lateral edge of lattice degeneration. When lying the patient flat, no communication between the 2 separate detachments was detected.

? Now how about another hole in the inferior detachment?

▶ No hole was found. There was only extensive lattice degeneration with a suspicious area at the lateral edge of it at 8 o’clock.

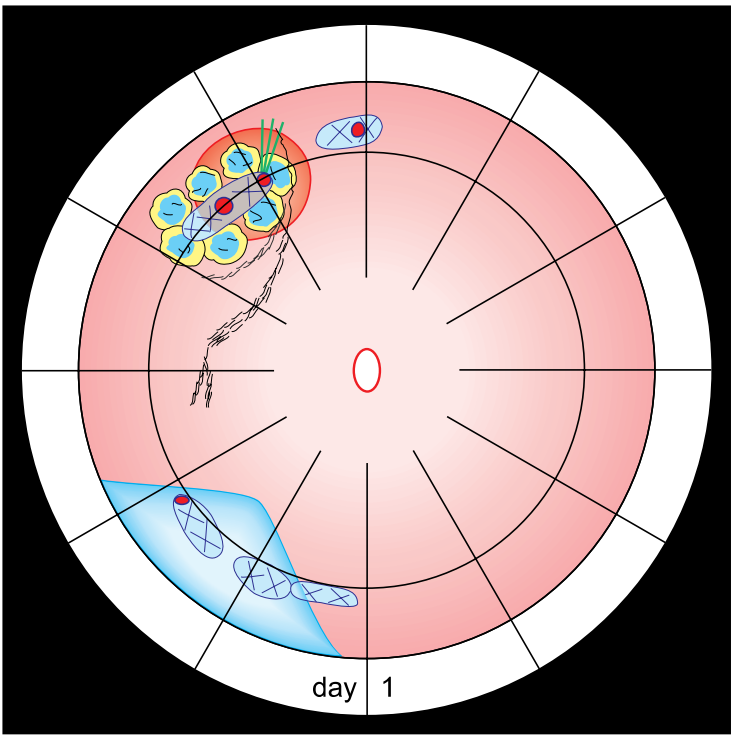


Fig. 9.**24 b** 1 day after insertion of a diagnostic balloon beneath the suspected break at 11 o'clock: The hole and the entire lattice is surrounded with cryopexy lesions. The superior retina had reattached and the inferior detachment had diminished in size, indicating that its fluid was originating from the superior break now being tamponaded.

? How would you proceed with this detachment?

▶ You could support the entire detachment with a segmental buckle from 6 to 12 o'clock.

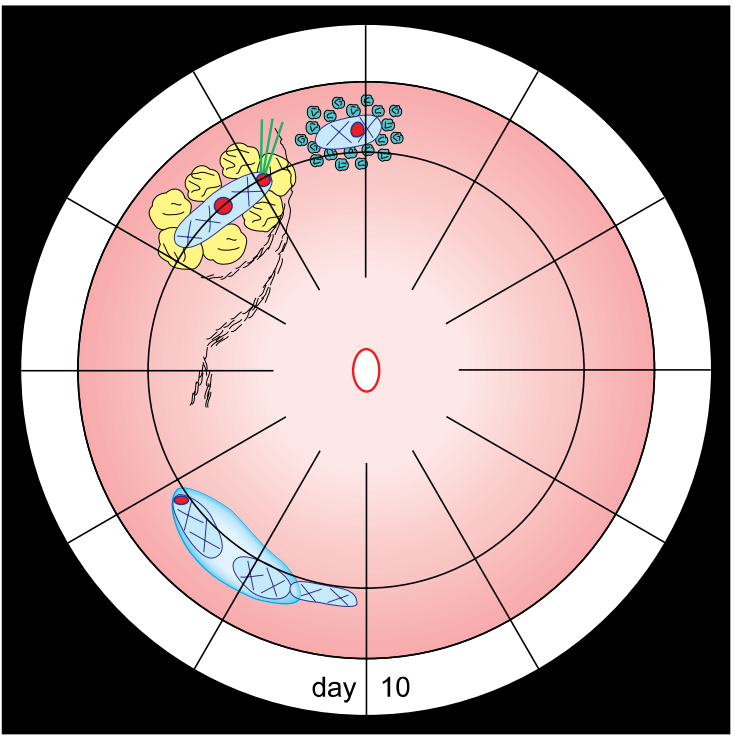


Fig. 9.**24 c** 10 days after balloon operation: The balloon was withdrawn after 8 days when the cryopexy lesions were pigmented. The lattice degeneration at 12 o'clock was surrounded with laser lesions. There is still a residual fluid around the inferior lattice degenerations.

? But what could you do instead, aiming at minimal surgery?

▶ Divide your treatment into parts.
Treat only what you know:
- Treat the hole at 11 o'clock that you have detected as being the cause of the superior detachment.
- Consequently, place a diagnostic balloon beneath the hole at 11 o'clock.

Only the lattice degeneration and the hole at its edge at 11 o'clock were treated with transconjunctival cryopexy. The hole was sup-

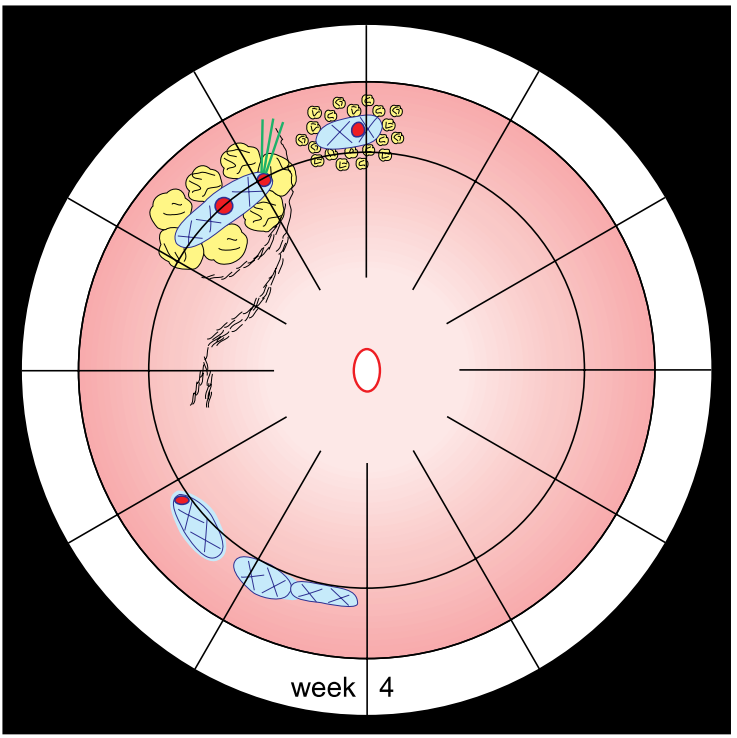


Fig. 9.**24 d** 4 weeks after balloon operation: The residual fluid had disappeared. No further treatment was added.

ported by a parabulbar balloon. The next morning the superior retina had reattached. To our surprise, the inferior detachment had also decreased in extent.

? Was the residual detachment a failure?

- **No**, since the extent of this inferior detachment had already been reduced due to the tamponade of the superior break. It was only residual fluid (Fig. 9.**24b**).
- Instead the patient was mobilized and advised to sleep with the head elevated.

? Why?

▶ To avoid shifting of the inferior fluid into the macula during sleep.

After 10 days the inferior detachment had further receded (Fig. 9.**24c**), and after 4 weeks the retina was reattached completely (Fig. 9.**24d**).

The untreated lattice degeneration at 12 o'clock, now reattached, was subsequently surrounded with laser lesions. The inferior lattice degeneration was not treated.

? Why?

▶ **Because:**
- It was too extensive for prophylactic treatment.
- It was located inferiorly.

This patient was informed about **"passive" prophylaxis** on a regular basis (see Part 1, Chapter 6, pp. 90–92). This regimen was especially indicated because the posterior vitreous membrane was not completely detached. Complete vitreous detachment developed after 4 years. The follow-up of this patient is 12 years and no additional prophylactic treatment has been performed, nor has a redetachment occurred.

▶ **Example 5: 2 separate detachments, the inferior one with a dense, uninterrupted pigment demarcation line**

In the superior bullous detachment there is a large horseshoe tear at 11:30 at the lateral edge of lattice degeneration. The inferior detachment has a convex border and is surrounded with a dense pigment demarcation line (Fig. 9.**25a**). No connection between these 2 detachments could be discerned. In the inferior detachment 2 small red spots could be detected, which did not appear to be holes, but more likely petechial hemorrhages.

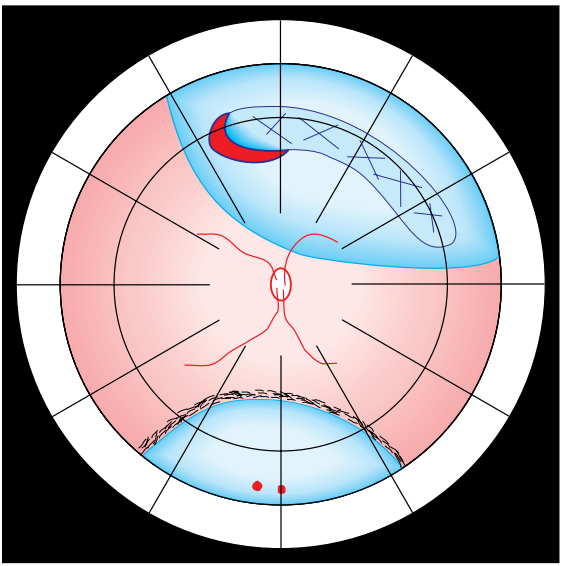


Fig. 9.**25 a** 2 separate detachments: The superior detachment has a large horseshoe tear at 11:30 at the lateral edge of lattice degeneration. In the inferior detachment, surrounded by a dense pigment demarcation line, there are 2 red spots representing petechial hemorrhages.

? How would you treat this somewhat atypical detachment?

▶ The treatment was divided into 2 steps:
- **Again, treat only what is known,** i.e., buckle the horseshoe tear in the superior detachment
- **Wait** for the outcome.

● **Keep in mind:**
- The disappearance of subretinal fluid occurs in a logical pattern in response to treatment.
- **Spontaneous disappearance of fluid provides the proof that the retinal break was found and tamponaded adequately.**

A diagnostic balloon was inserted beneath the horseshoe tear at 11:30, which was surrounded with cryopexy lesions. At the operating table again the anterior retina between the 2 detachments was

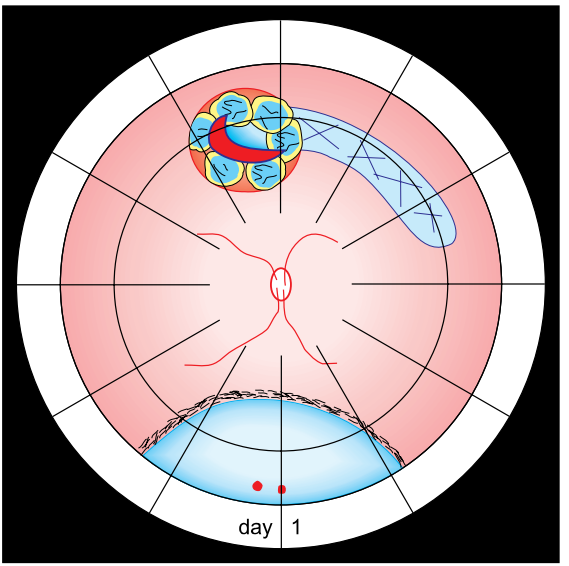


Fig. 9.**25 b** 1 day after insertion of a diagnostic balloon: To divide the treatment of this complex detachment into small procedures, a balloon was placed under the tear at 11:30 and the hole surrounded with cryopexy lesions. The inferior detachment was not treated. The day after surgery, the superior retina had reattached, but the inferior detachment had not changed.

examined with depression. However, no connecting fluid nor an inferior break was found. Consequently, the inferior detachment was not treated. The 2 inferior red spots, when re-examined with depression, were confirmed to be small hemorrhages.

The next day the superior retina had reattached, but the inferior detachment—not having been treated—had not decreased in size this time (Fig. 9.**25b**).

? Was this a failure?

Before doing too much too fast due to uncertainties, better reflect again:

- In the inferior detachment there was also no oral disinsertion present.
  The 2 red spots were interpreted as petechial hemorrhages.
- **Consequently, it is better to wait some days,** especially since the macula was attached.
- **The patient was mobilized.**

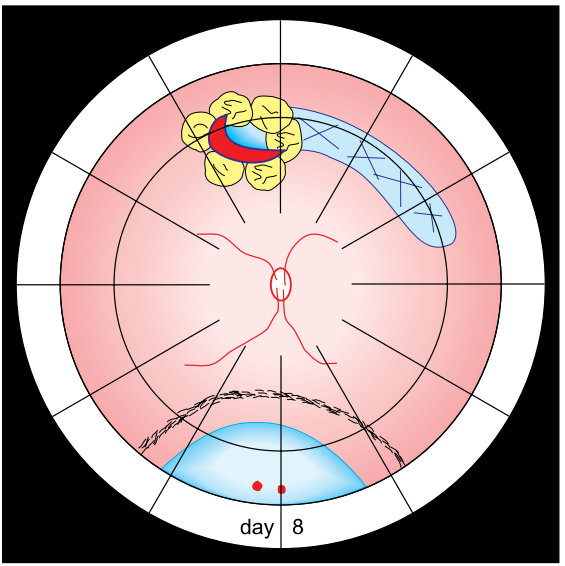


Fig. 9.**25 c** 8 days after balloon operation: The horseshoe tear at 11:30 was surrounded with pigmented cryopexy lesions, the balloon was withdrawn. In the meantime the inferior detachment had spontaneously regressed to some extent.

On the 3rd day we could perceive a slight decrease of the inferior detachment and on the 8th day this was substantial (Fig. 9.**25c**). As a result, no additional treatment was performed, the inferior residual detachment further decreased and after 3 months the fluid had almost completely disappeared (Fig. 9.**25d**).

This time the lattice degeneration adjacent to the superior horseshoe tear was not surrounded with prophylactic laser lesions. However, the patient was instructed to practice a **"passive" prophylaxis** on a regular basis. During the entire follow-up of 17 years the retina has remained attached.

? What did we learn from the last 2 examples, each of which presented with a *"separate" superior and inferior detachment?*

▶ **– First, buckle the break you have found in the superior detachment.**
– Do not perform prospective buckling in the inferior detachment in which you could not find a break.

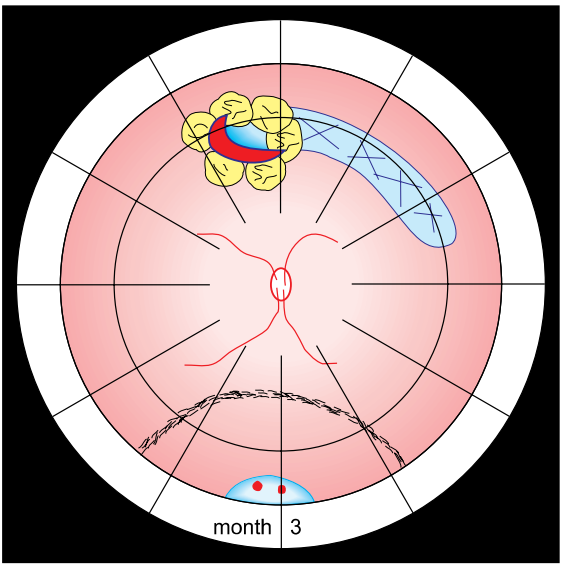


Fig. 9.**25 d** 3 months after balloon operation: The inferior detachment had further decreased without additional treatment. The superior lattice degeneration was not surrounded with laser lesions. The retina remained attached during 17-year follow-up.

- Reflect whether the inferior detachment could not be caused by the same break as the superior detachment, in spite of the fact that you could not find a connecting sinus between the 2 detachments.
- As a final reminder:
  Do not over-react with over-buckling.
  Instead, plan your treatment:
  - **As a logical approach, i.e.,**
  - **In steps and wait for the outcome.**
- Example 5 with **2 "separate" detachments** might have been misleading for you.

? Why?

The pigment demarcation line surrounding the inferior detachment could have suggested the presence of another tear, e.g., an oral disinsertion.

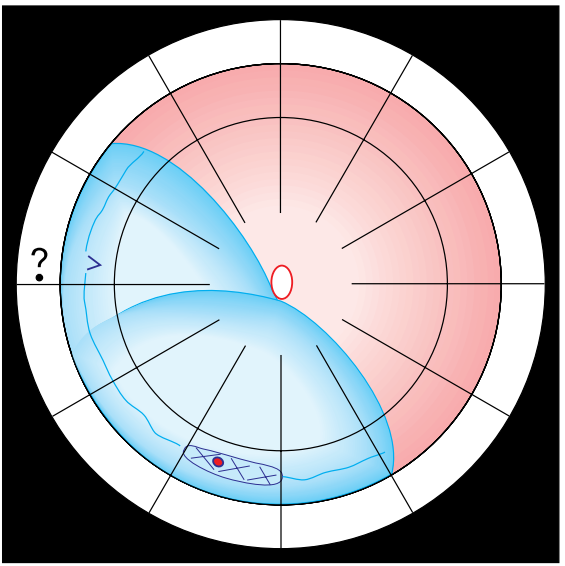


Fig. 9.**26 a** An aphakic detachment with a so-called traction line and no hole: The lattice degeneration between 6 and 7 o'clock has a pseudohole. Within the anterior traction line an irregularity at 9:15 was considered most likely to harbor the break, the localization of which would fit Rule 1 of how to find the primary break.

? How could you exclude *a priori* the possibility that the inferior detachment was not caused by an oral disinsertion?

- There was no tobacco dust within the vitreous.
- The vitreous was detached in this elderly patient, whereas in an oral disinsertion—mostly present in a younger patient—in general the vitreous is still attached.

Example 6: An aphakic detachment with a so-called anterior traction line and no hole

Here we have a 2-quadrant detachment in an aphakic patient (Fig. 9.**26a**). The anterior retina was accessible for examination, however, no certain hole could be detected [22]. There was a lattice degeneration between 6 and 7 o'clock with a pseudohole and a so-called traction line in the anterior retina from 5 o'clock to 10:30. There were no pigment demarcation lines. After a repeated search-

ing no certain hole could be found. Only a little tit at 9:15 in the area of the traction line could be made out. Since the macula was attached, placing a large prospective buckle in the area of the rectus muscle might have resulted in diplopia and in a dissatisfied patient. The indication for a gas operation with vitrectomy did not seem justified either.

Instead at the operating table the entire traction line was depressed again, but no certain hole detected. After that the little tit at 9:15 was still the most likely place to harbor a break; in addition its location fitted Rule 1 of how to find the primary break (see Part 1, Chapter 2.2, pp. 13–18). A diagnostic balloon was inserted in this area.

● To begin with, let us recall:
- **No certain hole was found.**
- **Therefore, a diagnostic balloon was inserted beneath the area of most suspicion, an area which—at the same time—fitted Rule 1 of how to find the primary break, i.e., to cause this pattern of detachment.**

The balloon was inflated with 0.8 ml of fluid. The next morning the entire retina was reattached despite not having discovered the exact position of the break (Fig. 9.**26b**).

? **What did you learn by the treatment of this detachment?**
And what do you have to do now?

▶
- The break you were looking for has to be on the buckle of the diagnostic balloon, otherwise the retina would not have reattached.
- As a result, the entire buckled area has to be secured by interrupted laser lesions.

? **Why?**

▶ To seal off the unidentified, but reattached break being located on the balloon buckle.

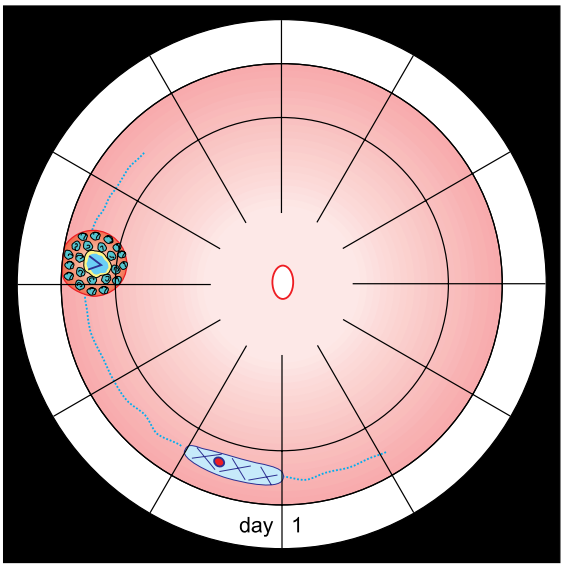


Fig. 9.**26 b** 1 day after insertion of a diagnostic balloon: The tit at 9:15 was localized with a cryopexy mark, the balloon inserted beneath it and the day after surgery the retina was reattached. Since the actual localization of the hole was not known, the entire area of the balloon buckle was secured with interrupted laser lesions. The inferior lattice degeneration was not treated.

? Why is this so important?

- To provide conditions that will sustain reattachment after removal of the balloon.
- Because after that, reattachment will only depend on sufficient adhesions around the break.

The inferior lattice degeneration was not treated. After 8 days the thermal lesions on the buckle had become pigmented, the balloon was removed. Fig. 9.**26c** represents the fundus after 9 days. The patient was asked to practice **"passive" prophylaxis** on a regular basis (see Part 1, Chapter 6.3, pp. 90–92). Subsequently, the anterior traction line receded and was no longer visible. In this aphakic eye the posterior vitreous was detached. The follow-up of this patient ranges at 9 years and the retina has remained attached.

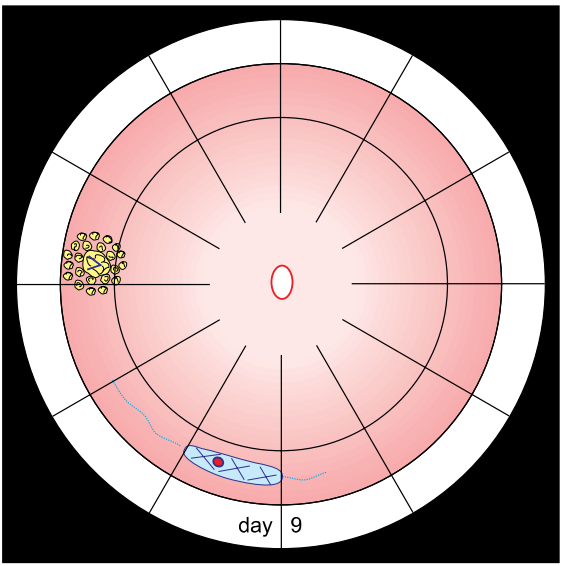


Fig. 9.**26 c** 9 days after balloon operation: The balloon was withdrawn after 8 days, the laser lesions had pigmented. In the subsequent 9 years no additional treatment was required.

? Let us review the 6 detachments, treated so far by a diagnostic balloon: What did we learn by using a parabulbar balloon as a diagnostic probe?

- With a parabulbar balloon you can test for the presence of a break in a suspicious area.
- The balloon can be used to exclude the presence of an additional questionable break and thus to limit the operation.
- The balloon provides the possibility of buckling a superior break, which first becomes visible behind a vitreous hemorrhage, providing the smallest surgical approach.
- If in this situation the retina should not reattach completely, then the remaining inferior detachment will have developed a new contour, which will indicate where to look for the second break (see Chapter 14.4, pp. 315–348).
- With the balloon procedure you can divide the treatment of selected complex detachments into 2 small procedures, and sometimes the 1st operation alone will be sufficient.

As a result, the diagnostic balloon can provide conditions for avoiding a large prospective procedure, such as a cerclage or a primary vitrectomy.

9.6.8 To Rescue a Failing Buckle

The balloon can be used to augment a failing scleral buckle [29] instead of performing a conventional secondary operation, i.e., sewing another sponge to the sclera, applying a cerclage to raise the buckle or injecting an intraocular gas bubble with or without vitrectomy.

When rescuing a failing buckle with a parabulbar balloon, the method of localization is different. The existing buckle interferes with the normally performed scleral depression over the break. The radian of the break, however, can be determined by scleral depression anterior to the existing buckle.

The distance of the break from the limbus is taken from the previous surgical record, if available. If not, it must be estimated. The bulge of the buckle can often be seen or at least be palpated. The conjunctiva is reopened, usually 7 mm from the limbus. It is advisable to use a sharp scarifier to dissect a passage through the superficial thickened Tenon's tissue, i.e., external to the surface of the buckle. This dissection is done so superficially that the movement of the knife can be observed beneath the conjunctiva. The balloon is inserted to the estimated position of the retinal break and then inflated with 0.7 to 1 ml of sterile water (Fig. 9.**27a**). Do not forget to check the central retinal artery for patency.

As the balloon expands, the existing buckle is pushed deeper into the eye. If the augmented buckle closes the retinal break, subretinal fluid is usually absorbed by the next day and the retina reattaches (Fig. 9.**27b**).

If more than 4 days have elapsed since the previous coagulation, the edges of the reattached break should be sealed off with laser applications.

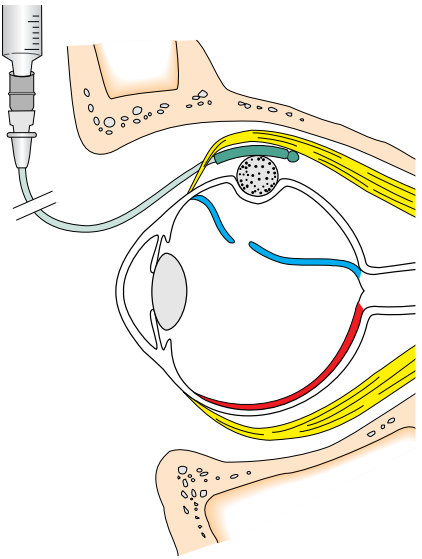


Fig. 9.**27 a** Sagittal section of the orbit showing a balloon being inserted to rescue a failing silicone sponge buckle. The deflated balloon has been inserted on top of the sponge. The retinal break is still detached.

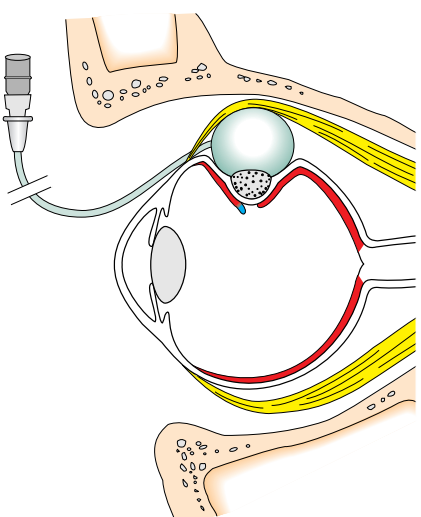


Fig. 9.**27 b** The inflated balloon has raised the existing buckle and brought it into contact with the retinal break ready for laser treatment. The retina has reattached.

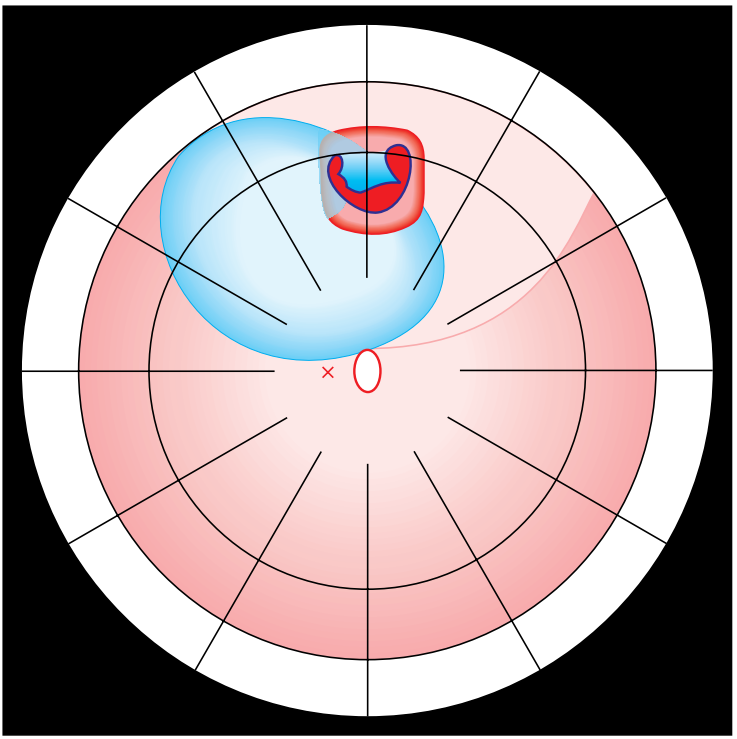


Fig. 9.**28 a** To rescue a failing scleral buckle: The horseshoe tear at 12 o'clock is too large for the explant. Its temporal edge is not in contact with the buckle, continues to leak, and has sustained the temporal portion of the detachment for 5 days. The cryopexy lesions around the tear are not presented. The lighter shaded area indicates the original extent of the retinal detachment.

In Figure 9.**28a** you see a detachment with a large horseshoe tear in the area of the superior rectus muscle. The tear was only partially tamponaded, i.e., the contour of the superior detachment that had crossed the 12 o'clock meridian had changed to a superior lateral detachment, indicating that the horseshoe tear was leaking on one side.

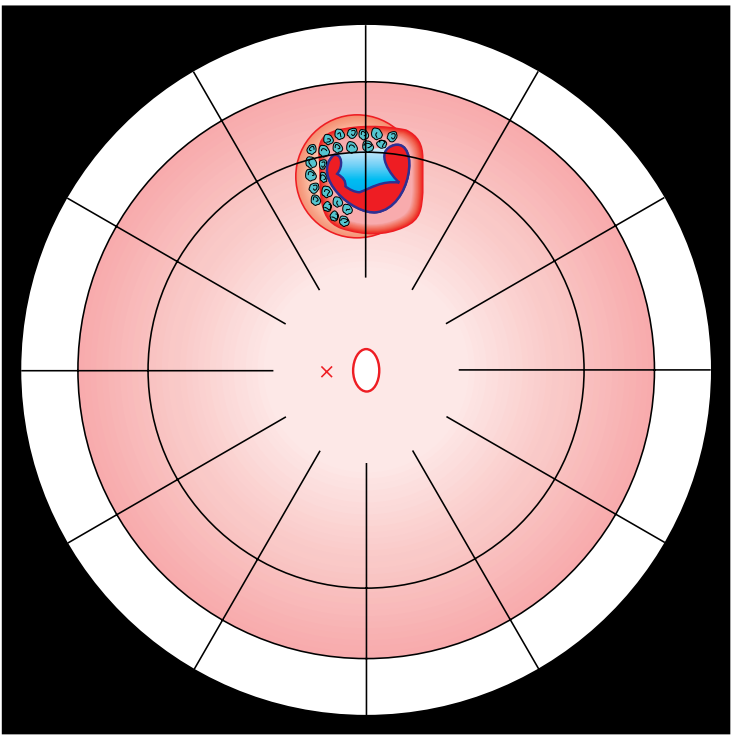


Fig. 9.**28 b** 18 hours after the balloon was inserted to augment the failing buckle: The tear and the retina reattached and laser coagulation was applied to the previously leaking edges of the tear. After pigmentation of the laser lesions (the remaining circumference of the tear is secured by cryopexy lesions, not presented), the balloon is withdrawn after 7 days. The retina has remained attached.

? What would you like to avoid when planning your reoperation?

- Enlarging the scleral buckle in the area of the muscle (diplopia!).
- Injecting an intraocular gas bubble (vitreous → PVR!).

- Raising the buckle by a cerclage (constriction → circulatory disturbances!).
- Intraocular gas with vitrectomy (→ cataract, anterior PVR, glaucoma, etc.).

? What could you do instead?

▶ Use a minimal extraocular approach by applying a parabulbar balloon.

Consequently a parabulbar balloon was inserted on top of the existing buckle and inflated with 0.8 ml of fluid (the central retinal artery has to be checked for patency!).

The next day the retina was reattached and the horseshoe tear stretched out on the enlarged radial buckle, being ready for laser treatment of its delayed reattached edges (Fig. 9.**28b**).

? What did we learn by treating this detachment?

▶ **With a balloon inserted on top of an existing buckle, you can:**
- **Broaden a buckle to compensate for an *inadequate tamponade* of the tear or**
- **Raise an *adequately positioned buckle*, which is too shallow.**

Let me explain how you can use a balloon inserted on top of an existing buckle in another way. As with a primary detachment—when being treated with a parabulbar balloon—if the break does not close off in a day, the parabulbar balloon can be enlarged with another 0.3 ml of sterile water on successive days until contact is obtained. The same principle can be used for an existing buckle, i.e., if a balloon is already inserted on top of it.

In such a detachment (Fig. 9.**29a**), the balloon will be placed on top of a circumferential buckle to raise it and thus to close off the breaks which are not settling. Apparently the buckle was too narrow. After successive inflations of the balloon, being inserted on top of the existing buckle, all of the 4 tears reattached. Afterwards they

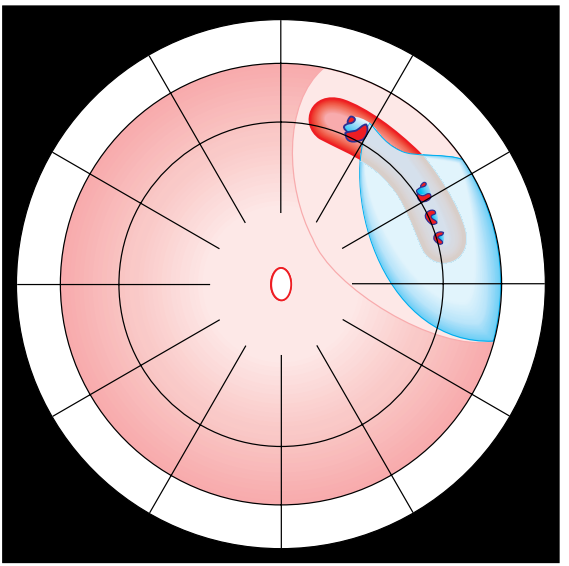


Fig. 9.**29 a** To rescue a failing scleral buckle: A superior lateral detachment with 4 horseshoe tears has responded only partially to a circumferential silicone sponge operation. The cryopexy lesions are not depicted to provide a better identification of the various tears and the changes in contour of the detachment. The lighter shaded area indicates the original extent of the retinal detachment.

were surrounded with laser coagulation (Figs. 9.**29 b, c**). After pigmentation of the lesions, the balloon was removed and the retina remained attached.

- **With this extraocular balloon** maneuver under local anesthesia you rescued the failing buckle and thus **avoided an intraocular** gas injection or a more invasive surgery as reoperation.

9.6.9 As Late Reoperation

The balloon can also be used as a late reoperation, i.e., for a detachment recurring long after its primary repair due to the development of a new break.

I will explain this to you using 2 examples in which the balloon procedure was applied as a minimal extraocular approach to

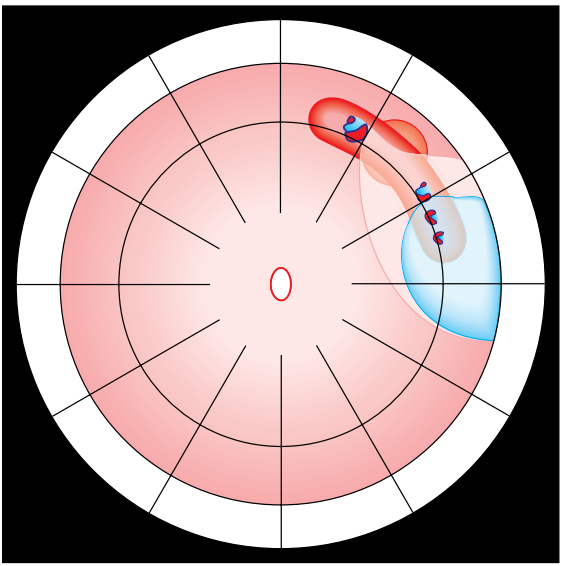


Fig. 9.**29 b** 16 hours after a balloon was inserted the detachment had receded to the level of the next most superior tear.

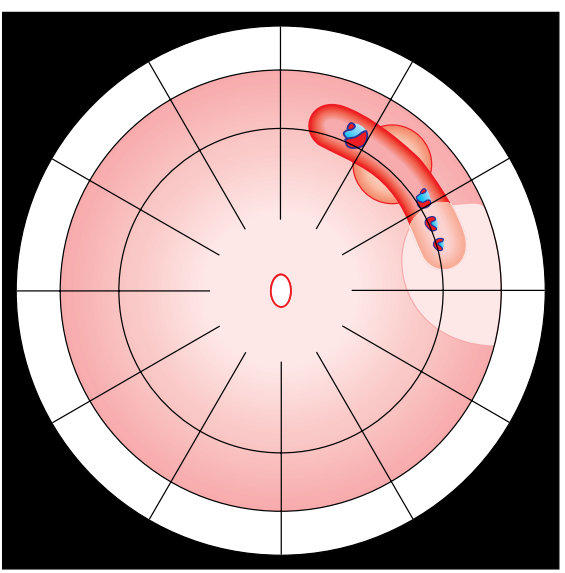


Fig. 9.**29 c** After additional injections of 0.3 ml of sterile water on 2 successive days, the inferior tears closed off and the retina reattached. The 4 tears were surrounded with laser lesions, and the balloon was withdrawn 8 days later. The retina has remained attached for 12 years.

buckle the new break. In the 1st patient, the detachment developed 22 years after diathermy and an intrascleral silicone rod implant. Actually redetachment had occurred some weeks after a cataract operation was performed (Fig. 9.**30a**).

? Why was the balloon selected as a late reoperation?

▶ **For the following reasons:**
- To avoid the hazards of perforation of a diathermized sclera in a last eye of the patient.
- To be able to perform the operation under topical anesthesia (cocaine 5%).

? Why?

▶ Since the patient's heart condition (heart attack 5 days before) permitted neither a general, nor a retrobulbar, nor a parabulbar anesthesia.

The patient presented with a bullous detachment which extended posterior to the buckle from 2 over 6 to 11 o'clock and anterior to it almost to 12 o'clock. The only tear that we had found was at 11:45, located at the anterior slope of the buckle. Since it was a superior tear and since it could have caused this type of detachment, a balloon was inserted beneath it on top of the existing buckle. The next day the superior retina was reattached. Since cryopexy could not be applied due to the existing buckle, the tear was surrounded with interrupted laser lesions after reattachment. However, there was still an inferior detachment (Fig. 9.**30b**).

? Was this a failure?

▶ **No,** reflect for a moment:
This is a residual detachment with all its typical features (see Part 1, Chapter 8.13, pp. 212–224).

? But what should you do now?

▶ Ask the patient to sleep with the head elevated, to prevent pooling of the fluid into the macula overnight, until the fluid has disappeared.

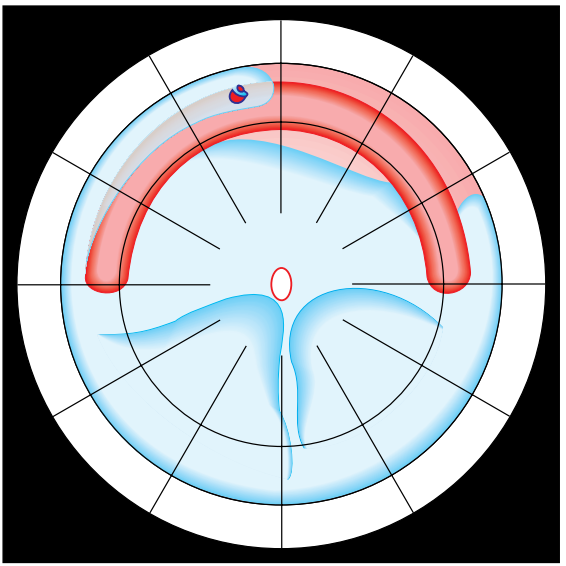


Fig. 9.**30 a** A late re-detachment 22 years after diathermy and an intrascleral silicone rod implant in the superior periphery: There is a new tear at 11:45 at the anterior edge of the buckle.

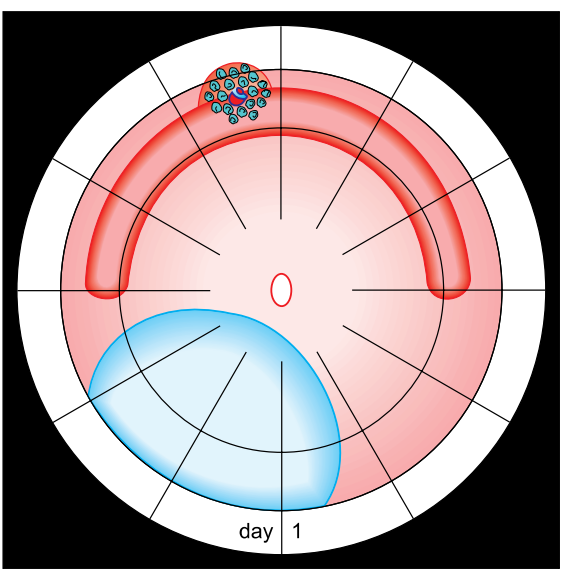


Fig. 9.**30 b** 1 day after a balloon was expanded on top of the existing buckle beneath the tear: Subretinal fluid had been absorbed, except for some residual fluid below. Until its complete absorption the patient was asked to sleep elevated to avoid macular detachment during the night. The reattached tear was surrounded with laser lesions.

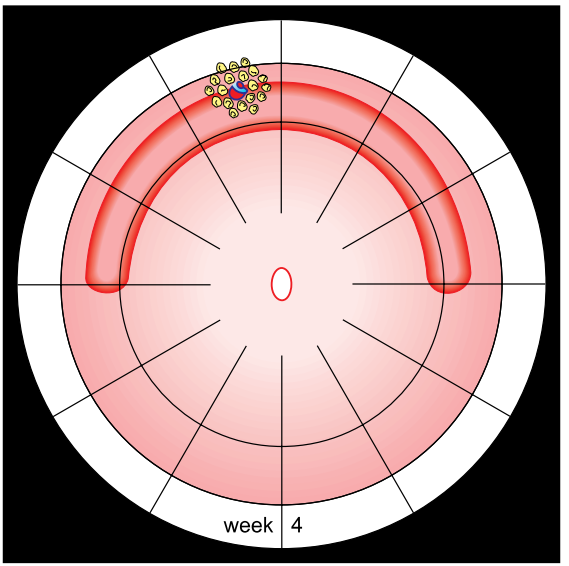


Fig. 9.**30 c** 4 weeks after balloon operation: The small horseshoe tear was sealed off with interrupted laser scars, the balloon had been removed, and the retina was completely reattached. It remained attached for the following 9 years.

After 1 week the laser lesions around the tear were pigmented and the balloon was withdrawn. In the subsequent 4 weeks the residual fluid disappeared (Fig. 9.**30c**). The retina remained attached for the following 9 years.

? What did we learn from this detachment which was reoperated with a parabulbar balloon?

- **A reoperation,** often implying difficulties in dissection and even harboring the risk of scleral perforation, can be converted into a small extraocular procedure,
  limited to the *area on top* of the existing buckle.
- The existing buckle will be raised **ab externo,** i.e., by the balloon inserted on top of it.
- Even such a reoperation
  can be done under topical anesthesia,
  as was the situation with this patient who had suffered a heart attack 5 days previously.

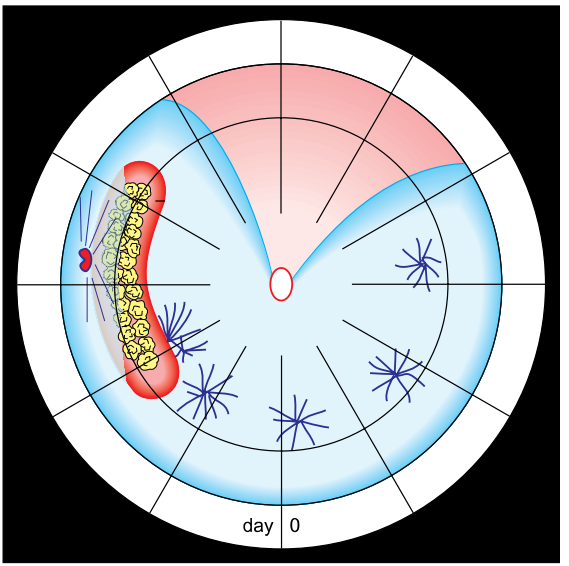


Fig. 9.**31 a** Balloon as late reoperation: A 3-quadrant detachment with PVR and starfolds in 2 quadrants in an eye with a previous buckle operation, diathermy, and tear anterior to the buckle at 9 o'clock. As a minimal approach for reoperation a parabulbar balloon was selected.

Here I will present another detachment in which a late reoperation was performed simply by inserting a parabulbar balloon (Fig. 9.**31a**). You even might recall this patient, because the reoperation was performed in a PVR detachment with starfolds in 2 quadrants (see Part 1, Chapter 8.18, pp. 252–279). In this 3-quadrant detachment the existing buckle had been buried in diathermized sclera and the only tear we had found was anterior to it at 9 o'clock. Reoperation consisted of a temporary balloon buckle beneath the tear in subconjunctival anesthesia. Delayed reattachment occurred, i.e., corresponding to PVR regression (Figs. 9.**31b, c,** and **d**).

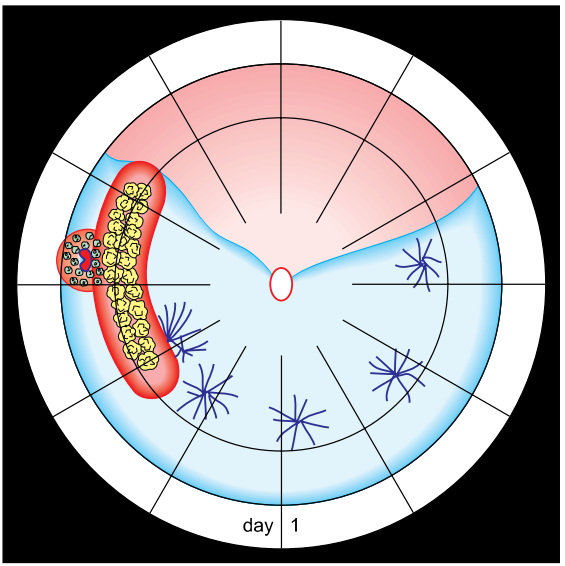


Fig. 9.**31 b** 1 day after balloon insertion under the horseshoe tear at 9 o'clock: The tear has reattached on the balloon buckle and has been surrounded by laser applications. The balloon will be withdrawn after 1 week, i.e., after pigmentation of the thermal lesions.

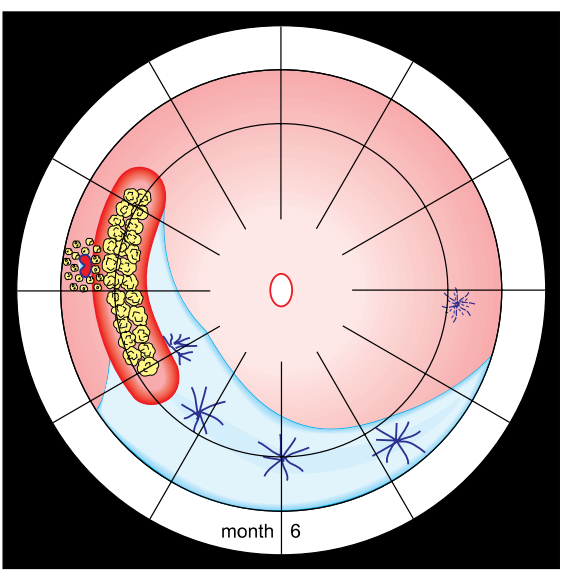


Fig. 9.**31 c** 6 months later: A residual traction detachment with concave contours and surface persists. The macula is reattached.

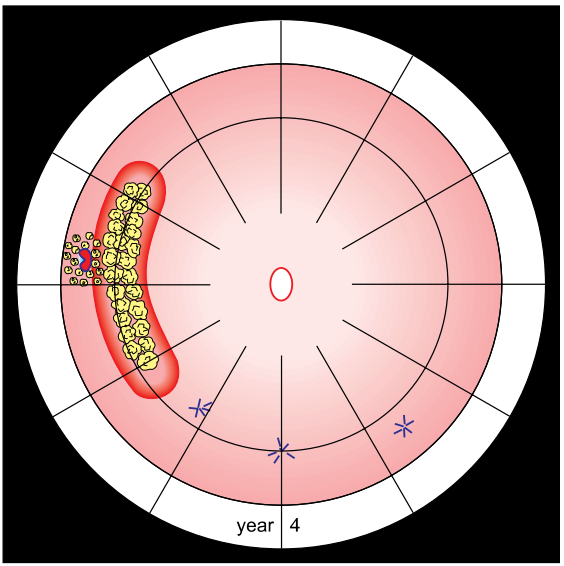


Fig. 9.**31 d** 4 years after balloon operation: The traction detachment has flattened, only remnants of starfolds are visible.

? But why did we select a parabulbar balloon as the method of choice for reoperation of this PVR detachment?

- It would represent the most minimal conceivable approach, since **small and extraocular,** essential in this detachment being already in limbo to progress into massive PVR.
- **To avoid the risk of a perforation during dissection** of **diathermized sclera.**
- **To avoid a vitrectomy,** at present still accompanied by early and late complications.
- To have the option of performing the **surgery with subconjunctival anesthesia.**

9.6.10 Staphylomatous Sclera

The balloon procedure qualifies for treating a break in a detachment with staphylomatous sclera [30].

? Why?

- Since no intrascleral sutures are needed with the balloon procedure.
- The final size of the buckle can be obtained in steps.

Here as well, a narrow channel is made beneath conjunctiva and Tenon's capsule with a blunt instrument. The deflated balloon is maneuvered with special care to the area to be buckled, slowly inflated, and even, if necessary, inflated in steps on successive days.

? Why?

To eliminate the risk of scleral perforation that might be induced by a sudden increase in pressure:

- To prevent this, a balloon can be inflated slowly and even on successive days to obtain the final volume for subsequent indentation.
- In contrast to this, a sponge has to be tied under a certain pressure and this cannot be modified substantially.

? What are then all of the advantages of applying a balloon in an eye with staphylomatous sclera?

- The **hazards of placing an intrascleral suture** in such an eye can be **avoided**.
- If a **large buckle** is needed, it can be obtained **in steps** by injecting small increments of fluid, even on successive days if necessary.
- An alternative **intraocular surgery can be avoided,** which is of importance if the patient still has a clear crystal lens.

An alternative that can be considered in such a detachment would be the injection of an expanding gas without vitrectomy, though the risk of secondary vitreous complications is greater in comparison to a temporary balloon buckle (see Chapter 11, pp. 271–287).

9.6.11 Detachment in a Glaucomatous Eye

Under the premise that there is only 1 break or group of breaks within 1 clock hour, the balloon procedure represents a treatment of choice in a glaucomatous eye. You will recollect that in a glaucomatous eye the use of an expanding gas would be fatal because it may result in a loss of vision.

? Why would you consider a balloon operation as an optimal approach in a glaucomatous eye?

- No extensive dissection of the anterior conjunctiva is needed. This is important if a filtering procedure should be required at a later date.
- The height of the balloon buckle can be obtained in steps, i.e., by injecting small increments of fluid and thus avoiding prior drainage of subretinal fluid or vitrectomy to create intraocular space.
- Even a very large buckle can be obtained in such an eye without the threat of an acute rise in intraocular pressure, since the large volume of the balloon buckle can be tapered, i.e., adjusted to the decreased outflow.

9.6.12 Balloon-Aided Vessel-Occlusion Technique

In this context the function of the balloon is 2-fold [31]:

1. **To reattach an avulsed vessel** on top of an attached retina or **to reattach a vessel crossing a detached horseshoe tear.** Both findings can cause recurrent vitreous hemorrhages.
2. **To close off the circulation within** such a vessel prior to its occlusion by laser coagulation.

? Why is it of importance?

To reduce complications, such as hemorrhage, during laser occlusion.

Let me describe the balloon-aided vessel-occlusion technique with the following 3-quadrant detachment (Fig. 9.**32a**). It has a horseshoe tear at 2 o'clock, and the view to the retina is slightly obscured due to a vitreous hemorrhage.

The 2 steps of the vessel-occlusion technique are:

1. **The horseshoe tear is tamponaded** by the parabulbar balloon, resulting in its reattachment, including the crossing vessel causing recurrent hemorrhages (Fig. 9.**32b**).
2. **The artery**, crossing the horseshoe tear, will be **occluded by laser coagulation**. In this maneuver the balloon, which is already in place, is used to *reduce the risk of severe complications* (Fig. 9.**32c**).

? What is crossing your mind in this context? In which way could the pre-placed balloon be of any help in reducing the complications to be expected during a thermal vessel occlusion?

▶ The parabulbar balloon can be further inflated to increase intraocular pressure (by compressing the globe) and thus temporarily slow down or even **stop the retinal circulation.**

? Which great advantage does this imply?

▶
- It will provide optimal conditions for a vessel occlusion with laser coagulation because the blood flow can be interrupted during that moment.
- As a result:
  The occlusion with laser coagulation can be:
  - safer (less risk of hemorrhage)
  - more effective (less laser energy needed).

? But how is such a vessel-occlusion technique performed?

▶ It is done at the laser slit lamp with the contact lens in place. The balloon is further inflated until the patient reports a loss of light perception, which implies that the retinal blood flow has stopped.

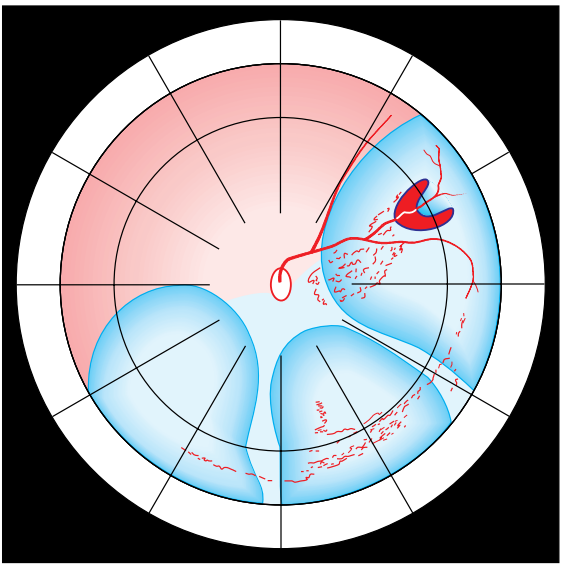


Fig. 9.**32 a** A bullous 3-quadrant detachment after a recurrent vitreous hemorrhage with a horseshoe tear at 2 o'clock, being crossed by an artery (cause of recurrent hemorrhages).

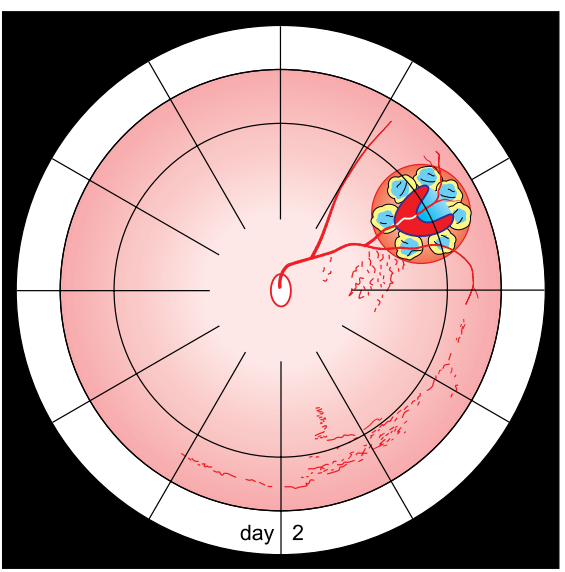


Fig. 9.**32 b** 2 days after balloon insertion beneath the tear: The retina is reattached.

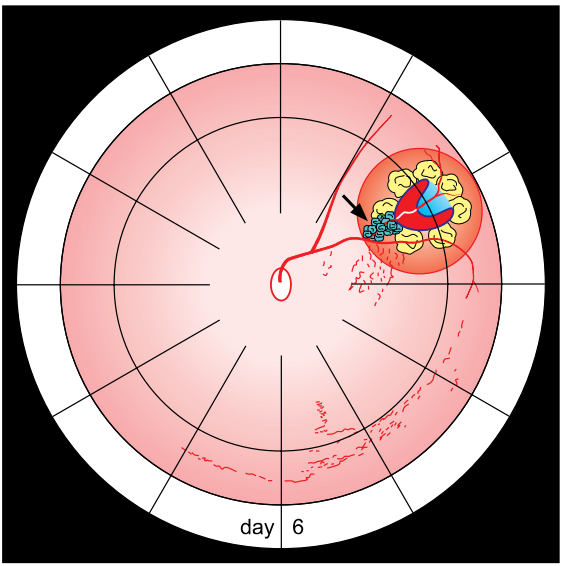


Fig. 9.**32 c** 6 days after balloon insertion: With the patient sitting at the laser microscope and the contact lens in place, the balloon is inflated with another 0.5 to 0.8 ml of fluid until the patient reports loss of light perception. At that moment the vessel occlusion with laser coagulations (see arrow) is performed. 3 minutes after the vessel occlusion has persisted, fluid of the balloon is withdrawn slowly until light perception is restored. The balloon is left in place for another day for the eventuality that another laser coagulation for vessel occlusion will be needed.

At this precise moment you will place your laser lesions, 500 µm in diameter, to the retina at either side of the vessel you intend to occlude.

? Why do you have to do this first?

▶ To turn the neighboring retina opaque, thus protecting the choroid, and avoiding the complication of choroidal hemorrhage during vessel occlusion with laser coagulation.

The same laser energy you have plotted to turn the retina opaque with a 500 µm spot, you will now apply with a smaller spot size, 200 µm in diameter, directly aimed at the vessel to be occluded. Laser

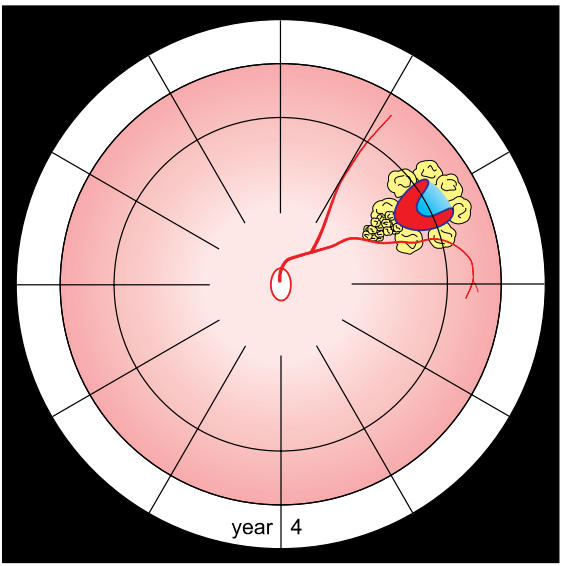


Fig. 9.**32 d** 4 years after balloon-aided vessel occlusion with laser: No recurrent vitreous hemorrhages have developed. Over time the occluded vessel regressed and was no longer discernible.

coagulation is continued until the vessel turns whitish. During these moments with maximal risk of a hemorrhage, the patient is asked to press in addition very hard against the contact lens.

? Why?

▶ To sustain for certain the interrupted vascular circulation during the moment of vessel occlusion with laser coagulation.

During the treatment no complications developed and the vessel was occluded. The balloon is slowly deflated 3 minutes later. If the vessel does not seem to be completely occluded the next day, the same procedure can be repeated without delay. Just re-inflate the parabulbar balloon and start over again.

After pigmentation of the thermal lesions around the tear, the balloon was withdrawn and the retina remained attached. The occluded vessel regressed over time and after 4 years it was no longer discernible, not even with biomicroscopy (Fig. 9.**32d**).

In the meantime 13 eyes with recurrent vitreous hemorrhages were treated in this manner. Not one vitreous hemorrhage or choroidal hemorrhage developed during or after this type of vessel-occlusion technique.

? What are the advantages of the balloon-aided vessel-occlusion technique?

- No invasive surgery is needed.
- Less laser energy is applied.
- Even if the vessel should rupture during the process of laser occlusion, the risk of hemorrhage will have become minimal.

? Why?

- The retinal perfusion is interrupted and if necessary, this condition can be sustained for some minutes if needed by increasing the volume of the pre-placed balloon.
- In addition a highly avulsed vessel can be first reattached by the pre-placed balloon and the balloon then used to stop the blood circulation during the laser coagulation for vessel occlusion.
- This technique offers another advantage:
  Since the avulsed part of the vessel can be *reattached* first, *vessel occlusion can be done at a more anterior portion* of the vessel (artery!), resulting in a smaller loss of visual field.
- Since no intraocular surgery is required with this technique, the lens will not be at risk.

9.6.13 Basic Balloon–Gas Procedure: Creating Space for an Intraocular Gas Injection

This technique will be discussed in details in Chapter 10.5, pp. 159–166 [32]. However, so much so far for the basic balloon-gas procedure: In this technique the parabulbar balloon is inserted prior to a gas injection and the balloon volume withdrawn to provide space for a simultaneous injection of a larger gas bubble. By applying this technique no prior drainage of subretinal fluid or vitrectomy are needed (Fig. 9.**33**).

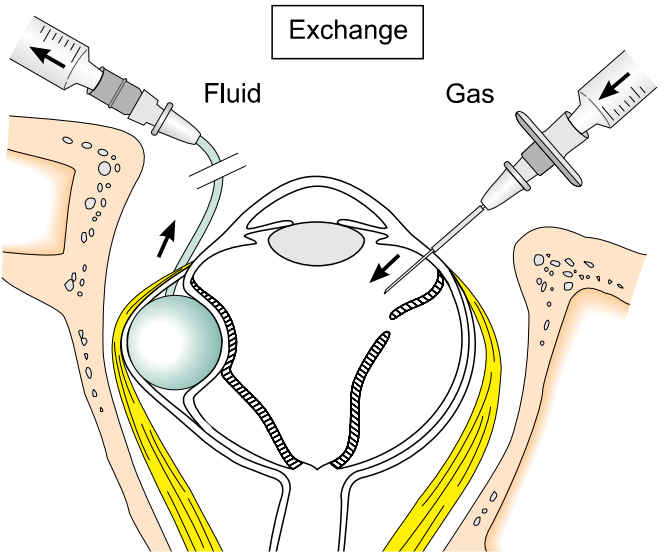


Fig. 9.**33** *Basic* balloon–gas procedure: The balloon is used for providing a kind of fluid–gas exchange. The intraocular space for subsequent gas injection is created by prior insertion of a parabulbar balloon that induces internal drainage of aqueous from the vitreous due to continuous oculocompression. About 2 hours later, the obtained intraocular space is replaced by an intraocular injection of gas combined with simultaneous withdrawal of balloon contents. This provides space for injection of a larger intraocular gas bubble without prior drainage or vitrectomy.

- **The advantages of the basic balloon-gas procedure are:**
  1. A gas with a **smaller expansion coefficient** can be selected,
     - since primarily a larger gas bubble can be injected.
  2. At the same time a gas with a **shorter intraocular duration** can be used,
     - since this will be of benefit to the vitreous, inflicting fewer complications.
  3. As a result, this procedure makes feasible
     - **a gas operation with less morbidity.**

9.7 Results

9.7.1 Anatomical Results

Recalling the multifold indications for the balloon operation, you will realize that this procedure can indeed provide a large spectrum of clinical applications. But as you will also experience, when starting with this technique, you have to optimize your diagnostics, and after that, step by step, you will move on to more complex detachments, subsequently becoming an expert in the full spectrum of this technique.

But when analyzing your results, you will also realize that you had a learning curve—as we did—and for this reason I will demonstrate to you how our indications for the balloon operation and the results changed in the 2 subsequent series:

- **In the 1st series** with 100 detachments *the indications were restricted.*
- **In the 2nd series** with 500 detachments the *full spectrum of the discussed indications were applied without restrictions.*
- **Finally, we found out that every *4th to 5th detachment* would be suitable for the parabulbar balloon operation.**

9.7.1.1 First Clinical Study

Patients

In this study 100 detachments with 1 break or a group of breaks within 1 clock hour, recruited by Lincoff in New York and Kreissig in Tuebingen [33] were treated with a parabulbar balloon between April 1977 and April 1978. In this series the balloon was applied for **uncomplicated detachments,** that is, reoperations or more complex detachments were not included. In Tables 9.**1** and 9.**2** the characteristics of the detachments and the retinal breaks are summarized. The distance of the breaks from the limbus ranged between 9 and 21 mm (average 14 mm).

Table 9.1 Preoperative characteristics of retinal detachments (n = 100)

Characteristics	n
Extent	
1 quadrant	38
2 quadrants	32
3 quadrants	15
4 quadrants	15
Macula	
Attached	50
Partially detached	11
Detached	39

Table 9.2 Characteristics of the retinal breaks (n = 100 detachments)

Characteristics	%
Shape	
Horseshoe	74
Round	20
Unknown	6
Location	
Superior retina	58
Under a horizontal rectus muscle	10
Under a vertical rectus muscle	18

? What about horseshoe tears? Were they also included in the treatment with a temporary balloon buckle?

▶ **Yes.** There were 74% horseshoe tears in this series.

▶ Results and reasons for failure

In 90% of detachments the balloon successfully closed the retinal break as intended. The retina reattached completely in 82%, partially in 8%, and in 10% the retina remained detached.

? What happened after the balloon buckle was withdrawn?
How often did the retina redetach after that?

▶ In 6% the retina redetached of which 2%—as we learnt—**were solely due to the fact that we had not surrounded the break sufficiently with thermal lesions, especially towards the ora.**

? What was the consequence?

▶ To continue with this procedure, whilst bearing in mind this cause of failure in the subsequent study.
As a result, in the 2nd study the rate of redetachments—as you will see later—dropped to 2.4% in spite of the fact that we had included more difficult detachments in the treatment.

After reoperation, including the redetachments and the primary failures, the retina was reattached and remained attached in 92% of detachments in our 1st clinical series. These results compare favorably with those of permanent buckling.

If, however, we divide these first 100 balloon-treated detachments in groups of 25 patients, a learning curve becomes apparent, i.e., the rate of reattachment had increased over time.

? What does this imply?

▶ That we had improved our technique of adequately positioning the parabulbar balloon, unsecured by sutures, beneath the detached break.

If, however, when beginning with this procedure you select your balloon operations more carefully, i.e., increasing the degree of difficulty step by step—as I tried to demonstrate by the order of indications selected for you—you will certainly avoid this problem.

9.7.1.2 Second Clinical Study

In this series 500 detachments with 1 break or a group of breaks within 1 clock hour were treated by Kreissig and the staff in Tuebin-

gen between November 1980 and September 1986 [26]. This time, however, the **full spectrum of indications was applied** (see Chapter 9.6, pp. 25–31). Some detachments which we had assigned for treatment represented a real challenge for us. However, as time went on, we became increasingly confident and competent with this procedure. With the following prospective balloon study,

? 4 questions should be answered:

1. In the absence of a permanent buckle, does the rate of redetachment increase during a follow-up of 2 years?
2. What are the complications: Early and late?
3. Will there be a postoperative diplopia after removal of the balloon buckle?
4. How is the recovery of visual function: Early and late?

Patients

Here are some characteristics of the 500 retinal detachments included in the study: In 216 eyes there was a myopia between –2 dpt and –25 dpt, in 61 eyes an aphakia, and in 1 eye a pseudophakia. **There were included 30 reoperations, 3 eyes with a previous perforating injury of the globe, 70 with a vitreous hemorrhage, and 5 eyes with a PVR grade C** (3 detachments with starfolds in 1 quadrant and 2 with starfolds in 2 quadrants).

The detachments had been present for less than 1 week in 18%, for 1 week to 1 month in 39%, and for 1 month to 3 years in 7%. In 36% the duration of the detachment could not be determined. In 73% the detachment was confined to 1 quadrant, in 18% to 2 quadrants, in 6% to 3 quadrants, and in 3% to 4 quadrants (Table 9.**3**).

Table 9.**3** Extent of retinal detachments (n = 500)

	n	%
1 quadrant	366	73
2 quadrants	91	18
3 quadrants	28	6
4 quadrants	15	3

? The following types of retinal breaks were present (Table 9.4):

- **Horseshoe tears in 70%,** round holes in 26%, oral disinsertion in 1%, and the nature of the hole was uncertain in 3%.
- **In 20% there were multiple breaks close together within 1 clock hour.**

Table 9.4 Characteristics of the retinal breaks (n = 500 detachments)

	n	%
Shape		
Horseshoe tear	351	70
Round hole	127	26
Oral disinsertion	6	1
Uncertain	16	3

In 73% the break was in the superior retina. In 37% (184 eyes) the break was localized less than 4 mm from the center of the rectus muscle, which meant the balloon had to be placed in the area of the muscle. In 47% of these eyes a horizontal muscle was involved and in 53% a vertical muscle. The tears were on average 14 mm from the limbus.

- **The most anterior break was 8 mm.**
- **The most posterior break 22 mm from the limbus.**

Operation

The balloon was inserted as previously described (see Chapter 9.4, pp. 9–18) under topical, subconjunctival, or parabulbar anesthesia.

In all of the 500 patients the retinal breaks were treated or only localized with transconjunctival cryopexy before insertion of the balloon. In 125 eyes, supplemental laser coagulation was added postoperatively to seal off the entire circumference of the reattached break (e.g., after insertion of a diagnostic balloon or in the presence of a bullous detachment). In most patients the balloon was decompressed by one half of its volume on the 7th day and withdrawn between the 8th and 9th day. A prospective plan called for the

patients to be examined 1 to 2 weeks after balloon removal, then at 3, 6, and 12 months and at yearly intervals thereafter. The mean follow-up ranges at 25 months.

▶ Results and reasons for failure

The balloon completely reattached the retina in 93% of eyes and partially in another 2%. After removal of the balloon, the retina redetached in 2.4% (12 eyes).

? What were the reasons for redetachment after removal of the balloon in these 12 eyes?

▶ **— A new break 7 (1.4%)**
— A primary break, reopened by increasing traction or insufficient adhesions around the break 4 (0.8%)
— A leaking balloon 1 (0.2%)

? What was the subsequent course of the 12 eyes that redetached after balloon removal? Were they finally reattached and by which procedure?

▶ **11 eyes were reattached by:**
— Segmental sponge 7
— Balloon 3
— Perfluorocarbon gas 1

As a result, 11 of the 12 redetached retinas were reattached and remained attached during the long-term follow-up.

? What about the retinas which were only partially reattached or still detached after 1 balloon insertion?

▶ **31 eyes were reoperated by:**
— Segmental sponge 23
— Balloon 3
— Perfluorocarbon gas (using balloon-gas procedure) **5**

? And what were the results after 1 balloon insertion and 1 reoperation?

▶ 490 eyes or 98% were reattached completely.

? And the results after 2 reoperations?

▶ **In only 4 of the 500 detachments a 2nd reoperation was performed consisting in:**

- **—** Segmental sponge 3
- **—** Vitrectomy 1

▶ **The retina was reattached completely in 99%** (Table 9.5).

? What were the reasons for final failure?

▶
- **— No hole 5 (1%)**
- **— Preoperative PVR**
  → persisting failure 1 (0.2%)
- **— Postoperative PVR 1 (0.2%)**

These results compare favorably with permanent buckling and also with pneumatic retinopexy (see Chapter 11, pp. 271–287). During the long-term follow-up the rate of redetachment was comparable with the results known from segmental buckling; it was even less than 0.5% per year. Admittedly, the detachments treated with a parabulbar balloon represented a favorable group of patients, since they had only 1 break or multiple breaks within 1 clock hour.

Table 9.5 Anatomical results of 500 detachments after 1 balloon insertion and reoperation

Retinal reattachment	Balloon insertion (n = 500)	Balloon removal (n = 500)	1st reoperation (n = 42)	2nd reoperation (n = 4)
Complete	466 (93%)	454 (91%)	490 (98%)	493 **(98.6%)**
Partial	11 (2%)	11 (2%)	3 (0.6%)	2 (0.4%)
None	23 (5%)	35 (7%)	7 (1.4%)	5 (1%)

9.7.2 Functional Results

Almost all of the 407 patients whose macula was attached prior to insertion of the balloon regained their preoperative visual function within 3 days. At 6 months, 2.8% had a more than 2-line loss. The reasons for this late loss were, in order of frequency: Age-related macular degeneration (the same as in the fellow eye!), a vitreous hemorrhage, or redetachment.

In the 26 patients whose macula was partially detached before the balloon operation (except for 1 surgical failure), regained visual acuity had improved and depended on the duration of macular detachment [34].

Of the 67 patients who had a detached macula before insertion of the balloon, macular reattachment occured in 64:

- At 3 weeks, 49 had some improvement in central vision.
- At 6 months 59 were improved.

As was to be expected, the amount of improvement reflected again the duration of the macular detachment, which in this series was days to months.

? But what was the most astonishing observation concerning the balloon procedure?

▶ The rapid recovery of visual function.

Noteworthy is the following.

● **If the macula was preoperatively attached:**
- Full visual function returned within 3 days after surgery.
- Most importantly, there was no subsequent deterioration of visual acuity in comparison to the fellow eye during the long-term follow-up.

You would have expected this:

? Why?

▶ There was no constricting element nor any buckle present 1 week after surgery, nor was an intraocular surgery performed, harboring secondary complications, such as, cataract, glaucoma, etc.

Besides this good news concerning postoperative visual function, **there is more good news:**

- After 1 balloon insertion the retina had reattached in more than 9 out of 10 detachments.
- It had remained attached after removal of the balloon in more than 9 out of 10 detachments during the long-term follow-up (mean 25 months).

9.7.3 Complications

Complications from the balloon operation were infrequent. Initially, we observed some superficial corneal erosions.

? Why did a corneal erosion occur?

▶ Because of improper placement of the emerging end of the catheter. However, this complication can be avoided if special care is taken to lead the catheter postoperatively away from the cornea, which can be easily done (see Fig. 9.**9**).

A choroidal effusion occurred in 1 eye (0.2%).

? What was so special about this 1 eye with postoperative choroidals?

▶
- It was a myopic eye of −22 dpt, which in addition had undergone 3 previous operations.
- The balloon was withdrawn and the choroidals subsided with corticosteroid treatment after a week.

In 1 eye a macular pucker developed 10 months after reattachment of the retina, but visual acuity remained at 20/30.

The major complication, common with segmental sponges, namely infection or extrusion of the explant, did not occur since the balloon was withdrawn after 1 to 1 1/2 weeks. Diplopia, the 3rd complication, was only present as long as the balloon was in place, and after withdrawal of the balloon the muscles functioned normally again.

Here another question you might raise:

? What about the possibility of infection as long as the balloon is in the parabulbar space?

▶ In **none** of the 500 patients an infection was observed.

And another question:

? — What would you do if you had to operate on an eye with an infection (i.e., hordeolum externum, purulent dacryocystitis, etc.)?
— Would it not be too risky to apply a balloon?

▶ **No.**
Instead, in these detachments the temporary balloon just represents a special indication.

▶ **This is due to the following facts:**
- The balloon catheter provides, by its exiting tube, a kind of drainage for a possible infectious secretion.
- The possibility of removing the balloon buckle at any time is optimal: As soon as the first sign of infection is suspected, it can be removed just after withdrawal of its fluid, i.e., without any delay or any preparation for operating room privileges.
- **The passage of the removed balloon catheter can be used:**
  - To obtain an optimal culture of the infection for microbiology.
  - To support any systemic antibiotic treatment by simultaneous local injections through this opening.

9.7.4 Conclusion

The balloon operation is analogous to the nondrainage procedure with segmental sponges, since both are based on the principle of an elastic structure, being initially compressed against the globe. This causes a rise in intraocular pressure and, due to the subsequent decrease in intraocular pressure, the sponge or the balloon expands further into the indentation which it has created to close off the retinal break.

- **But the balloon buckle has an additional advantage:**
  - Even after surgery it is accessible via its catheter, i.e., its size can be augmented, and thus reoperation can be avoided if the placed balloon buckle is too shallow or slightly off center to close the break.
  - By injection of another 0.5 to 1.0 ml of fluid via its catheter, **the diameter of the balloon buckle can be enlarged by 2 to 4 mm and another surgical intervention be avoided.**

The balloon catheter is a versatile instrument for the repair of selected retinal detachments, that are caused by 1 break or a group of breaks within 1 clock hour. The reattachment rate is comparable to that obtained with segmental buckling without drainage. However, with this procedure only a temporary buckle is used, implying fewer intraoperative and postoperative complications.

- In addition the balloon can be inserted under local or even topical anesthesia.

At the same time it causes a minimal surgical trauma to the eye since scleral suturing is not required, thus eliminating the risk of scleral perforation.

? Postoperative infection is practically impossible: Why?

▶ Because the balloon catheter represents only a temporary foreign body and, if needed, topical antibiotics will sterilize the conjunctival opening and its passage.

A postoperative refractive error does not occur because the contour of the eye is not permanently altered and there will be no persistent muscle imbalance. The balloon technique represents an additional instrument in the retinal surgeon's armamentarium. In a consecutive series about 1 out of 5 retinal detachments can benefit from this minimal extraocular procedure with a temporary buckle.

The rate of redetachments after balloon withdrawal, which was 6% in our first series, fell to 2.4% in the last 500 detachments.

This was the result of special care taken to seal off the operculum of the tear towards the ora serrata with 2 rows of laser or 1 row of almost contiguous cryopexy lesions.

? How are the advantages of the balloon operation to be defined?

- The patient undergoes minimal surgical trauma.
- No intraocular complications.
- No extraocular complications.
- No diplopia.
- Only topical or parabulbar anesthesia is needed.
- The possibility exists of postoperatively enlarging the diameter of a parabulbar balloon buckle by a further 2 to 4 mm without any surgical intervention.
- No cosmetic defect.
- A fast and optimal recovery of visual function.
- Even if you have failed with the balloon procedure you do not jeopardize or delay any additional surgery.

? And now the answers to the questions posed at the beginning:

1. The absence of a permanent buckle will result in early redetachment (limited to the 1st weeks after balloon removal) in 2.4%; thereafter sustained reattachment is comparable to a series with a buckle in place.
2. There are practically no complications.
3. After removal of the balloon there is no diplopia.
4. There is a fast and optimal recovery of visual function. During long-term follow-up visual acuity is not jeopardized by secondary complications, since the balloon is removed after 1 week.

The favorable results of the 2 clinical series presented are supported by comparable reports of various authors in the literature [35–42]. The publications originate from Eastern and Western countries.

- Another advantage of the balloon operation is that you can perform this procedure on an outpatient set-up as “office repair” [43].

Precisely this issue meets the demands our present health system is imposing on us. As a result, the balloon procedure might acquire a special importance in the future, since this issue is arising in North and South as well as East and West. Consequently, if you are urged to perform low-budget surgery with a minimum of instruments, i.e., without the need for a high-technology set-up in the operating room, and you are confronted with an old or infirm patient, you might decide upon the balloon procedure.

- However, as a precondition:
  - **This surgery requires a *maximum of* preoperative diagnostics**
  - **Thereafter it can be performed with a *minimum* of time**
  - **Still providing a *maximum* of long-term visual function.**

Regained visual acuity will not be jeopardized by a high rate of re-detachments requiring reoperations or secondary complications requiring additional operations in comparison to the fellow eye.

- **These are the facts about minimal extraocular surgery with a temporary balloon buckle.**
- **And they show that it is much what can be achieved by using it.**

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10 Temporary Gas Tamponades without Drainage: Minimal Intraocular Surgery for Retinal Detachments

10.1 History

The use of an intraocular gas bubble in retinal detachment surgery was first described by Ohm in 1911 [1]. At that time, however, the importance of the retinal hole in relation to a retinal detachment was not yet known. Ohm injected air into the vitreous via the drainage site (7 mm from the limbus).

? Why did Ohm inject air into the vitreous?

▶ To compensate for the loss of intraocular volume after drainage and
To push the *retina* back into place.
– It was a good idea.

He applied the method in 2 patients, and the retina reattached. Yet the gas technique did not gain importance.

In 1938, Rosengren [2] re-introduced the use of an intraocular air bubble for the treatment of a retinal detachment.

? What did Rosengren do differently?

▶ He used the intraocular air bubble
To tamponade the *retinal hole* after drainage (Fig. 10.**1**).

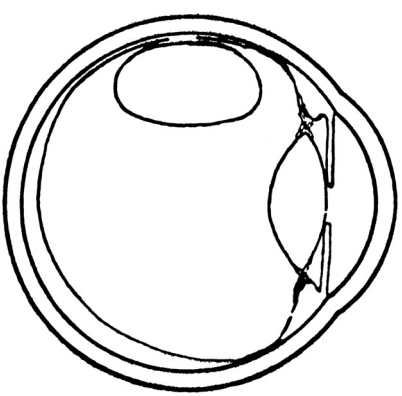


Fig. 10.**1** The use of an intraocular air bubble to treat a retinal detachment by tamponading the retinal hole, first performed by Rosengren in 1938 (Figure from [2]).

In contrast to Ohm, Rosengren had the advantage that Gonin [3] had since pointed out that the retinal hole is the cause of retinal detachment. Rosengren integrated this concept into his gas operation. That a gas bubble would not go through a retinal break was an original concept.

Today, this concept is obvious to all those, who are knowledgeable about the surface tension of a gas bubble.

Now a question you might raise:

? Did the Rosengren technique improve the rate of reattachment?

▶ **Yes:**
- It improved by a further 10% the results of retinal detachment surgery, which up to that time consisted only of diathermy around the break and drainage.
- The rate of reattachment rose to **77%**.

Rosengren's operation restored the intraocular volume with gas, flattened the retina with gas, and tamponaded the diathermized break. However, there was a drawback; the gas did not tamponade the break long enough.

? Why?

▶
- You might recall that air has a half-life of $1^1/_2$ to 3 days (this is dependent upon how old you are and whether you are a high myope).
- The tamponade with air did not last long enough in some eyes for a retinal adhesion to develop sufficient strength to secure the retinal break.
- The time required to develop a secure retinal adhesion is at least 7 days.

You might remember that after 1 week the retinal adhesion is strong enough to secure a retinal break, e.g., when a temporary balloon buckle is removed after 1 week (see Chapter 9.3, pp. 5–8). The maximum of a retinal adhesion after thermal coagulation is reached at 12 days (see Part 1, Chapter 7.2, pp. 96–109).

- **Bearing these facts in mind, Rosengren's final results were as follows:**
  - A certain number of detachments pulled apart on the 3rd or 4th day when the air tamponade had disappeared.

However, the information available today about the time it takes for a retinal adhesion to develop sufficient strength was not available in 1938. This information did not become available until more than 30 years later, after extensive animal experiments had been performed [4,5].

Redetachment after the Rosengren procedure called for a better procedure. Retinal surgeons did not give up and the search for a better method continued.

- In the early 50's various scleral buckling procedures were developed that yielded better results than the intraocular gas tamponade—though the air injection represented a significant conceptual advance.

▶ **But the idea for an external tamponade of the break was first realized by Custodis [6] in 1953:** He reduced extensive buckling then in practice to a buckle limited to the area of the break. In addition, he eliminated drainage of subretinal fluid. This new concept was made feasible by the use of elastic plombages. However, there were complications that jeopardized the acceptance of this procedure. Full thickness scleral diathermy facilitated scleral abscess in a number of patients and the explant Polyviol, made of gum Arabic, Congo red, and polyvinyl alcohol, was irritative.

▶ **In 1963 Lincoff modified this operation [7,8] to eliminate the complications induced by the explant and diathermy:** The cryosurgical detachment operation was developed (see Part 1, Chapter 8.1, pp. 126–127).

▶ **The operation was further refined during the 1970's: The so-called minimal extraocular surgery for retinal detachment (Kreissig [9])** provided optimal results with a reattachment rate of substantially above 90%.

● **Any good, new treatment will, however, either have unexpected complications or can be replaced by something better, e.g., for special indications.**

There was indeed a small group of detachments (about 7%) which proved unresponsive to minimal extraocular surgery, i.e., to segmental buckling without drainage.

? **For which retinal detachments might external buckling have reached its limits? Which detachments will cross your mind?**

▶ – Giant tears
– Tears at the posterior pole
– Multiple tears close together, but at different latitude.

Having perceived the limits of scleral buckling, in 1965 Lincoff started animal experiments with various gases in search of a gas that would persist in the eye for a longer time than air. At that time the expansion potential of a gas (which would provide conditions for a nondrainage procedure with a gas) was not yet an issue. The longevity of an intraocular gas bubble depends largely upon its solubility. Sulfur hexafluoride (SF_6) proved to be the best of the gases initially tested.

▶ **Therefore, in 1967 Lincoff re-introduced the gas technique, limited to detachments not suitable for scleral buckling** [10, 11]. **He had replaced air by SF_6** which stays twice as long in the eye. With this **modified gas technique** the problem of the Rosengren technique—a tamponade of too short duration—was eliminated.

● **The injection of SF_6 was, however, preceded by drainage of subretinal fluid,** but it could provide a tamponade of sufficient intraocular duration for a retinal adhesion to develop. It was this which represented the progress.

Additional reports about the clinical use of SF_6 followed from: Norton [12], McLean and Norton [13], Abrahms et al [14], Fineberg et al

[15], Laqua and Wessing [16], Kreissig [17], Kroll et al [18], Hausmann [19], etc.

10.2 Sulfur Hexafluoride (SF_6)

10.2.1 History

Sulfur hexafluoride or SF_6 (Fig. 10.**2**) had been used in medicine for pneumothorax procedures. That was one of the reasons why Lincoff assumed it would not be toxic and might be suitable for the eye [10,11].

First of all let us recapitulate:

? Why was SF_6 preferred to air?

▶ Because it remained twice as long as air in the vitreous.

? Why did SF_6 remain in the eye longer?

▶ **SF_6 is an inert gas** that is relatively insoluble in the watery vitreous and therefore stays in the eye for a longer period.

SF_6 is colorless and odorless. It doubles its volume over a period of 24 to 48 hours.

Sulfur hexafluoride
SF_6

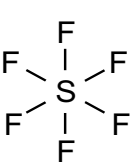


Fig. 10.**2** The chemical structure of SF_6, the first expanding gas, that was used in detachment surgery.

? Why does the increase in volume occur?

▶ **SF_6 expands** because blood gases, i. e., nitrogen, oxygen, and carbon dioxide, diffuse into the intraocular gas bubble. At equilibrium the volume of the SF_6 bubble has increased 1.9 times. It takes about 48 hours to reach the peak volume.

The disappearance or absorption time of SF_6 is twice as long as that of air. It takes 6 days for the bubble to diminish to half volume and 3 to 4 weeks for the last small gas bubble to disappear. However, for clinical use only the so-called half-life of a gas bubble, representing the time of a therapeutic gas volume, is of clinical interest (see Chapter 10.3, pp. 121–148).

? What about intraocular complications, since SF_6 will be in the vitreous longer?

▶ I assume you are recalling the previous statement: Every new treatment will eventually present some complications or limitations.

A temporary increase in intraocular pressure can occur. However, if the eye has a normal outflow and care is taken in the postoperative positioning of the patient's head (not to occlude the chamber angle by the gas bubble), a rise in intraocular pressure can be avoided. A posterior subcapsular cataract can develop if more than 1/3 of the lens capsule is subtended by the gas bubble. The FDA assigned a special toxicity to SF_6 due to traces of toxic contaminants, such as, sulfur pentafluoride or hydrogen fluoride, present in commercially available SF_6 containers. However, toxicity of SF_6 to the retina could not be found, as confirmed by Fineberg et al after electron microscopic studies in monkeys and rabbits [15].

▶ **In the subsequent years the gas operation with SF_6 evolved to become a technique of choice for the treatment of detachments not suitable for scleral buckling:**

- Either because of the extent
- Or the localization of the tear or tears.

- **However, with this gas technique, drainage of subretinal fluid was again needed** to provide a large enough intraocular space for the gas injection.
- This was a relative drawback in the treatment of retinal detachment.

? Why?

- Because already with segmental buckling (sponge operation), drainage of subretinal fluid was no longer needed.
- You also will recall that nondrainage constituted the essentials of a minimal procedure with a minimum of complications.

▶ **Convinced of the advantages of a nondrainage procedure, Kreissig had been trying since 1974 to transfer this concept to the upcoming gas technique** for special tears unsuitable for buckling [17].

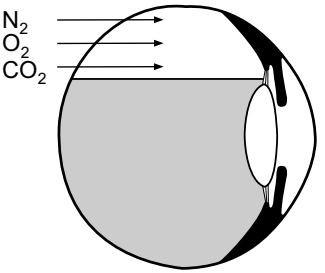
? How to sustain nondrainage with the gas technique?

▶ **It crossed our mind that we could use the expansion potentials of the gas** (Fig. 10.**3**) in the same way as we had already been using the elasticity of the sponge to obtain, in spite of nondrainage, a larger tamponade. This was enabled by the egress of intraocular fluid.

For this reason we tried to use the expansion potential of the gas when we began to treat selected problem detachments with SF_6. The aim was to further reduce the morbidity of the gas operation. Actually we wanted to limit this procedure to a gas injection with cryopexy or laser coagulation and without drainage.

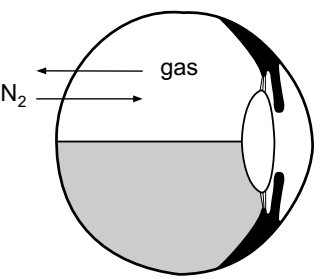
▶ **Between 1974 and 1978 Kreissig [17] succeeded in applying this SF_6-gas technique without drainage and additional thermal coagulation** in 6 problem detachments.

Fig. 10.**3 a** An expanding gas is injected into the vitreous. The bubble will expand to maximal size as nitrogen, oxygen, and carbon dioxide diffuse into the bubble.



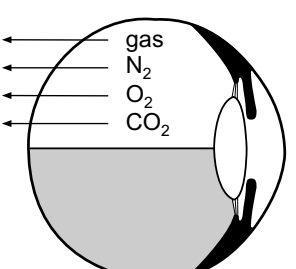
Gas bubble before expansion

Fig. 10.**3 b** The expanding gas has acquired its maximal volume. An equilibrium is reached when the rate of nitrogen diffusing into the bubble is equal to the diffusion of the expanding gas into the surrounding fluids.



Gas bubble after expansion, equilibration with blood gases

Fig. 10.**3 c** The gas bubble starts to decrease in volume gradually as the gases diffuse into the surrounding fluids.



Gas bubble dissolution

Thus, the 1st detachment operations with expanding gases and without drainage were performed between 1974 and 1978.
At the Meeting of the German Ophthalmological Society in 1978 the first results of this gas technique were reported [17]. Here are some details of this clinical study with SF_6.

10.2.2 Clinical Study with Expanding-Gas Operation without Drainage

The expanding-gas operation without drainage, described by **Kreissig** in 1979 (17), was applied in a small series of detachments, not suitable for external buckling, by using SF_6 combined with cryopexy and/or laser coagulation. As you might recall, several years later the indication of this gas technique was extended to the treatment of uncomplicated detachments by Dominguez in 1985 [20] and by Hilton and Grizzard in 1986. However, not aware of the report of Kreissig in 1979 on the use of SF_6 without drainage, **Hilton re-introduced this gas technique without drainage as "pneumatic retinopexy"** [21].

In our series the expanding-gas technique was applied to the following 15 problem detachments: 9 giant tears (extending from 75° to 195°), 3 reoperations with moderate PVR, and 3 detachments with breaks at the posterior pole. In 6 of these detachments SF_6 was injected without prior drainage of subretinal fluid.

You might raise the following question:

? Why, in 1979, was the indication of the expanding-gas operation without drainage not also extended to uncomplicated detachments, as Hilton and Grizzard did 7 years later?

- Our main reason was the **morbidity** associated with **intraocular gas:**
  Postoperative PVR had caused failure in 6 out of 15 problem detachments treated.
- A second and more cogent reason was that **in 1979, an optimal alternative, i.e., the balloon operation representing as well a temporary tamponade without drainage, became available for uncomplicated detachments** [22].

? But why was the balloon operation preferable to the expanding-gas operation?

- The balloon procedure was also a **minimal** operation because no scleral sutures were needed.
- But it was an **extraocular procedure,** i.e., there was no need to drain or to enter the vitreous for an intraocular injection.
- Therefore, with the balloon operation the risk of **postoperative PVR was minimal at 0.2%** in comparison to the higher incidence with pneumatic retinopexy at 4% [23].

These were the 3 reasons why, as of 1979, we preferred the balloon operation as treatment for uncomplicated detachments.

- As a result, the **expanding-gas operation** was reserved **for complicated detachments**, not suitable for scleral buckling.

Let us return to SF_6 and the results we obtained in treating problem detachments.

Anatomical results

The expanding-gas operation had failed in all 3 eyes with preoperative PVR because the **intraocular gas caused a progression of PVR.**

Of the 9 detachments with a giant tear, 6 were reattached and 3 failed due to the development of PVR.

Of the 3 detachments with holes at the posterior pole, all of them were reattached and it was achieved:

- Without redetachment after the gas bubble had receded.
- Without reoperation.

- **Therefore, in 1979 we had concluded that for detachments with hole(s) at the posterior pole and to a lesser degree giant tears the expanding-gas operation without drainage represented a procedure of choice** [17].

Complications

As already pointed out, the worst complication of intraocular gas was the development of **PVR**. An abrupt increase in intraocular pressure or the development of a persisting cataract was not observed. Subcapsular opacities in the posterior lens capsule disappeared within days after the gas bubble had been absorbed. The favorable results concerning the lens were obtained by postoperative positioning, which kept at least $^2/_3$ of the lens free from contact with the gas bubble.

Functional results

In 9 of the 15 problem detachments the retina was reattached with the expanding-gas technique. The visual acuity remained unchanged, if the macula was attached preoperatively, or it increased. The increase in visual acuity was between 20/100 and 20/20. During the follow-up (4 months to 4 years) the visual acuity remained unchanged.

10.2.3 Conclusion

The results of the *expanding-gas operation with SF_6, performed without drainage in 6 out of 15 problem detachments, were encouraging.* Reattachment was obtained in all of the 3 detachments with **posterior holes.**

- **Therefore, detachments with posterior holes seemed to represent the indication of choice for the expanding-gas operation.**

The expanding-gas operation also proved to be better than external buckling in the treatment of a detachment with a giant tear: In 6 out of 9 eyes with a tear between 75° and 195° in extent the retina was reattached.

- **In detachments with a giant tear the gas technique represented an atraumatic procedure with:**
  - Optimal postoperative visual acuity
  - No deterioration of visual acuity during long-term follow-up.

Today the reattachment rate of giant tears can be further improved by combining the expanding gases with prior vitrectomy and, if needed, liquid perfluorocarbons.

The high incidence of postoperative PVR experienced after treatment with intraocular gas prevented us from extending the expanding-gas operation without drainage into the treatment of uncomplicated detachments.

- **Instead, as of 1979, we treated uncomplicated detachments with the balloon procedure which also provided:**
  - Nondrainage
  - A temporary tamponade, but **in addition:**
  - **An extraocular approach** (see Chapter 9.3 pp. 5–8)
  - Significantly less postoperative PVR than with the expanding-gas technique (later called pneumatic retinopexy), since the vitreous had not to be entered when applying a parabulbar balloon (see Chapter 9.7, pp. 92–98).

10.3 The Perfluorocarbon Gases

10.3.1 The Cyclo-Perfluorocarbon Gas

The first report on an intraocular injection of a perfluorocarbon gas was by **Vygantas et al [24] in 1973**. They used octafluorocyclobutane or C_4F_8 (Fig. 10.**4**) in their attempt to find a non-toxic gas, which would be more slowly absorbed than air. Vygantas et al demonstrated that C_4F_8 and SF_6 were superior to air in terms of longevity in the vitreous. C_4F_8 would stay $7^1/_2$ days in the vitreous and seemed to be less toxic than SF_6.

Octafluorocyclobutane
C_4F_8

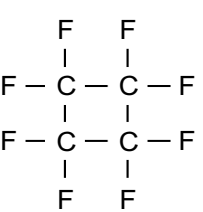


Fig. 10.**4** Chemical structure of C_4F_8, a cyclo-perfluorocarbon gas, with an expansion coefficient similar to that of SF_6.

? Why did C_4F_8 not become popular for detachment surgery?

- This was not due to the toxicity or adverse side effects of this gas, but—as is often the case in research—something better and more versatile appeared at that time.
- The straight-chain perfluorocarbon gases were extensively tested in animal experiments and in clinical studies. These gases provided a spectrum of intraocular longevities and, in addition, expansile potentials.
- Suddenly it was feasible for the surgeon to select the appropriate gas for the individual detachment and to perform again a surgery without drainage of subretinal fluid.

10.3.2 The Straight-Chain Perfluorocarbon Gases

These gases were studied in detail first in animal experiments and then in clinical trials by **Lincoff, Kreissig, and their retinal fellows from 1980** [25,26] to 1996 [27–29].

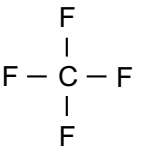
10.3.2.1 Physical Properties

There are 4 straight-chain perfluorocarbon gases (Fig. 10.**5**): CF_4 (perfluoromethane), C_2F_6 (perfluoroethane), C_3F_8(perfluoropropane), and C_4F_{10} (perfluoro-*n*-butane). These gases are inert, colorless and odorless like SF_6 or C_4F_8.

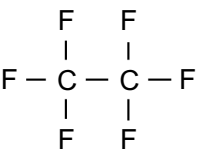
- As the length of the carbon chain increases, the solubility decreases. This results in an increase of expansile ability and intraocular longevity of the gases.

The specific gravity of the gases is less than that of intraocular fluid and therefore the gas bubble can exert a buoyant force superiorly. The gas can push the retina against the pigment epithelium and, because of surface tension, the gas bubble will not pass through the retinal hole.

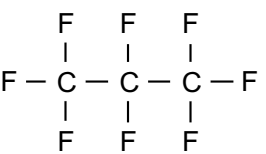
Perfluoromethane
CF_4



Perfluoroethane
C_2F_6



Perfluoropropane
C_3F_8



Perfluoro-*n*-butane
C_4F_{10}

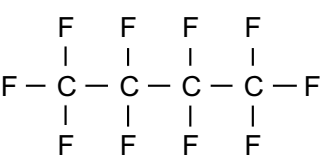


Fig. 10.**5 a** Chemical structure of the 4 straight-chain perfluorocarbon gases: Intraocular expansion and longevity varies with the length of the carbon chains.

▶ Intraocular longevity

The straight-chain perfluorocarbon gases came about when we (Lincoff, Kreissig, and the retinal fellows) were looking for a gas that might last longer than SF_6 in the eye.

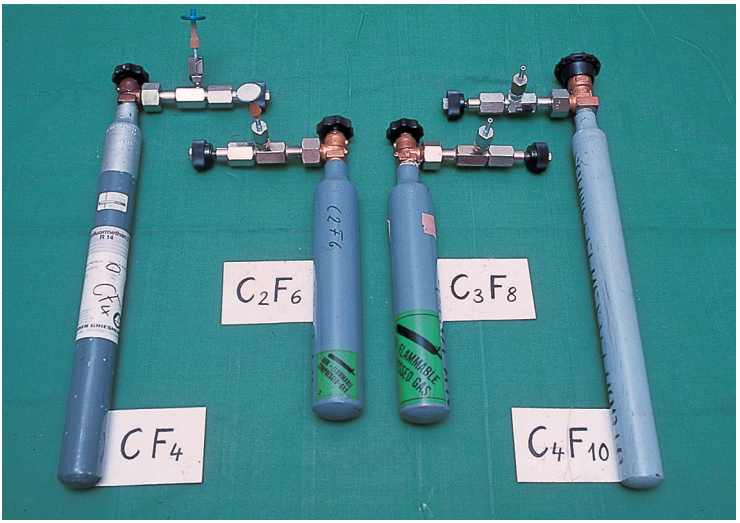


Fig. 10.**5 b** 4 perfluorocarbon gases in gas tanks of laboratory size.

An optimal gas should remain in the eye for at least as long as it takes for a retinal adhesion of sufficient strength to develop; this takes 1 week [4,5].

You will also recollect that the Rosengren technique sometimes failed because the air left the eye too early. SF_6 stayed in the eye longer, but for some detachments it was not yet an optimal gas.

? Why?

- Either the tamponade was not long enough, e.g., for the development of secure retinal scars around a complex tear formation.
- Or the volume after expansion was not large enough, e.g., to cover a posterior break.

As the chain of the perfluorocarbon gases increases in length, the insolubility of the gas increases. You should know that it is not the

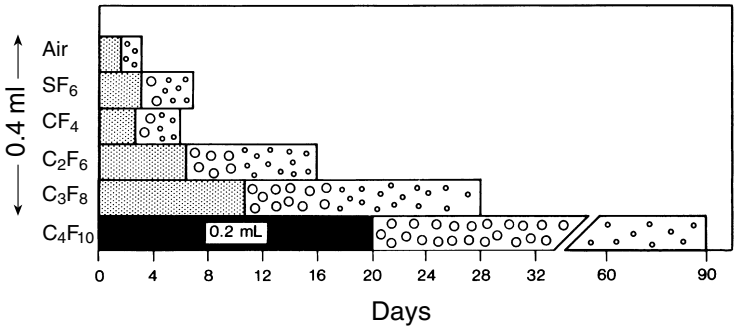


Fig. 10.**6** Disappearance times of intraocular gas in rabbit eyes: Bars compare intraocular disappearance times of 0.4 ml of air, SF_6, CF_4, C_2F_6, and C_3F_8 with 0.2 ml of C_4F_{10}. The solid or shaded portion of bars represent the time taken for half of the maximum of expanded volume to disappear. The remainder of bars demonstrates the disproportionately long time that it takes for small bubbles to be absorbed [30].

molecular size of the gas, but its insolubility that leads to a longer duration of the bubble in the eye.

? How does a longer intraocular duration of a gas bubble come about?

- A gas can only leave the eye in a fluid phase.
- A gas has to go into solution in order to leave the eye, that is, to cross the blood aqueous barrier.

Now, for your recollection, some physics which is needed to understand the following: Because the blood gases, such as N_2, O_2, and CO_2, are more soluble than the perfluorocarbon gases, they diffuse more rapidly across the blood aqueous barrier towards the gas bubble, resulting in expansion of the perfluorocarbon bubble [25]. In the next Figure (Fig. 10.**6**) you see the longevity of the 4 perfluorocarbon gases, the data which were obtained in animal experiments [30]. CF_4 has a longevity almost identical to that of SF_6; C_2F_6 stays in the eye 3.3 times longer than SF_6, C_3F_8 stays 6 times longer, and C_4F_{10} stays in the eye 13 times longer.

● However, **the total length of time a gas stays in the eye is of no use for a tamponade,** since in the last days or weeks **only small bubbles** are present.

For instance, C_4F_{10} has left the eye of a rabbit at 90 days, but weeks before there are only small bubbles present. Therefore, the total longevity of a gas bubble in the eye is not the significant factor that a surgeon would like to consider when selecting a gas for an optimal tamponade.

? **But what is important when you select a gas as tamponade?**

▶ **The time at which you will still have a therapeutic volume:**
- It is the volume for a sufficient tamponade.
- Therefore, when talking about longevity of a gas, we define it better as the **half-life of a gas.**

As you will recall, small residual bubbles of a gas are of little value for a retinal tamponade, and they persist for an unproportionally long time in the eye. When the disappearance time of the 4 gases was plotted on a log scale [26], it was found that the disappearance rate plots as a straight line.

● This indicates that the gases disappear as a first-order exponential function, and so can be talked about in terms of **half-life.**

You will notice that the slope of the line in the diagram is the same for the same gas (Fig. 10.**7**), regardless of how much of it was injected into the eye. This is because its disappearance rate, i.e., the half-life, is the same whether you start with 1 ml or 2 ml of gas. This data was obtained in a rabbit model. The rabbit retina is thinner than that of the human; therefore, the gases will disappear less rapidly in patients. The half-life of the 4 perfluorocarbon gases in patient eyes is diagrammed in Figure 10.**8**. This data was condensed in a Table (Table 10.**1**) to facilitate memorizing and looking it up as needed (e.g., in the operating room, at rounds).

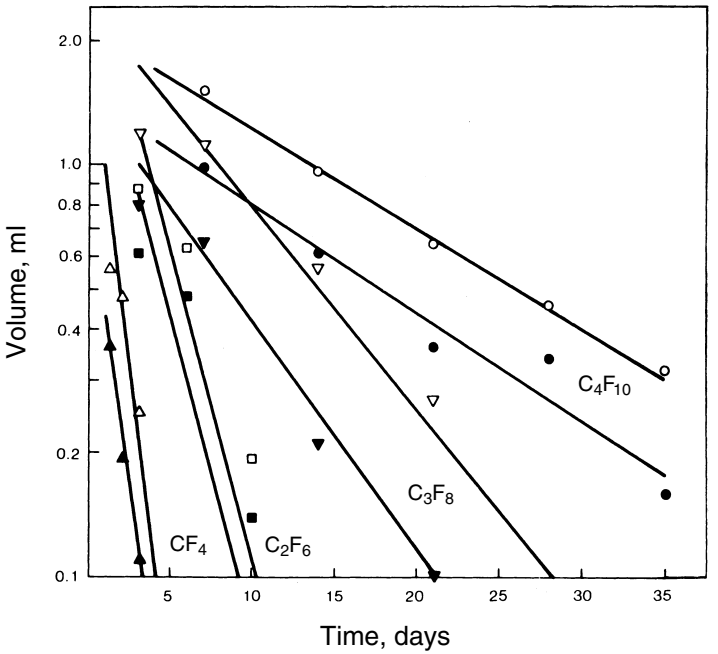


Fig. 10.7 Disappearance rates of 4 perfluorocarbon gases in rabbit eyes: CF_4, C_2F_6, C_3F_8, and C_4F_{10}. Volume is plotted against time on logarithmic scale. Closed symbols indicate data points for initial injection of 0.2 ml; open symbols indicate data points for initial 0.3 ml injection. Volume determinations of less than 0.1 ml are not included [26].

Now let us transfer this knowledge to a clinical situation.

— **If you start, for example, with an injection of 0.3 ml of undiluted C_2F_6 into the vitreous:**

- After 3 days the volume will be 1 ml.
- After 12 days it will be 0.5 ml.
- After 24 days only 0.25 ml, a little bubble of no therapeutical value remains.

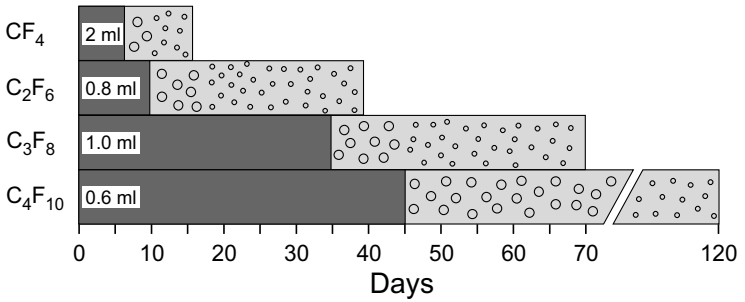


Fig. 10.**8** Disappearance time of the 4 straight-chain perfluorocarbon gases in patient eyes: The volumes injected varied according to the retinal problem to be treated. The dark gray portion of the bars indicates the time taken for the expanded volumes of gas to diminish to half volume [31].

– **If, however, you start with 0.6 ml of C_2F_6:**
- After 3 days it will expand to 2 ml.
- After 12 days it will be 1 ml.
- After 24 days it will be 0.5 ml, after which only small bubbles will remain.

Seeing all 4 gases in perspective:

? C_2F_6, with a half-life of 10 to 12 days, seems to be the ideal gas: Why?

▶ Because it provides a therapeutic bubble during the time it takes for a maximal adhesion to develop from laser or cryopexy treatment (see Part 1, Chapters 7.2.2 and 7.2.3, pp. 98–101).

The retinal adhesion reaches maximal adhesive strength at 12 days. During subsequent months it will remodel, but its adhesion will not increase further. You might remember that a light or medium lesion matures in 12 days and a heavy lesion in 14 days. So 12 days represent the time a gas bubble must tamponade a retinal break to obtain a maximum of adhesions around it. The half-life of the gases C_3F_8 and C_4F_{10} is much longer, being 20 to 24 days and 45 days respectively.

Table 10.1 Half-life of 4 perfluorocarbon gases in patient eyes.

Gas	Longevity (days)
CF_4	6
C_2F_6	10
C_3F_8	35
C_4F_{10}	45

? However, such a long half-life of a gas is unnecessary: Why?

▶
- **Because gases serve no purpose beyond 12 or 14 days.**
- **Instead, they only increase morbidity, i. e., PVR and new breaks.**
- **This also implies that whatever you want to achieve with an intraocular gas bubble, will have to be obtained within 12 days, the time needed for the development of a maximum of adhesions around the tears.**

Admittedly, early in our gas research and clinical work [17, 30] we thought that a longer gas tamponade might inhibit proliferative vitreoretinopathy (PVR), but this proved not to be the case.

On the contrary:
- Gases provoke a break down of the blood aqueous barrier, which might **provoke PVR.**

Consequently:
- **The shorter period a gas remains in the eye, the better.**
- **Whenever possible, select a shorter acting gas, such as CF_4 or C_2F_6, for the retinal problem.**

▶ Expansion

Expansion is another aspect of the perfluorocarbon gases [25]. Because the perfluorocarbon gases are relatively insoluble and if you have an insoluble perfluorocarbon gas on one side of the blood

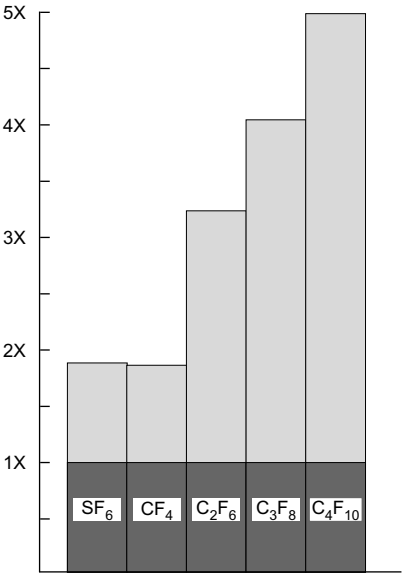


Fig. 10.**9** Expansion of the 4 perfluorocarbon gases and SF_6 in patient eyes [31].

aqueous barrier and nitrogen, oxygen, and carbon dioxide on the other, the more soluble gases will diffuse into the eye. All 4 perfluorocarbon gases, because they are less soluble than the gases in the blood stream, increase in volume when they are injected into the eye. This occurs over a short time.

- **The maximal increase in volume of all 4 gases occurs during the first 24 hours:**
  - Therefore, during this period it is necessary to measure the intraocular pressure at intervals if diminished outflow of the eye is suspected.
  - **The expansion of CF_4 is complete in 1 day, and of C_2F_6, C_3F_8, and C_4F_{10} in 3 days** (Fig. 10.**9**).

These data are condensed in a Table (Table 10.**2**) to facilitate looking them up as needed (e.g., in the operating room).

Table 10.2 Expansion of 4 perfluorocarbon gases in patient eyes.

Gas	Intraocular expansion
CF_4	x 1.9
C_2F_6	x 3.3
C_3F_8	x 4.0
C_4F_{10}	x 5.0

The expansion potential of the perfluorocarbon gases can be used to one's advantage, i.e., as already practiced with SF_6 [17], to avoid drainage of subretinal fluid and still obtain a large intraocular gas bubble.

▶ Clinical example

If you want to have a 1 ml bubble to tamponade 2 superior tears, such as the ones in Figure 10.**10a**, you can **inject 0.3 ml of C_2F_6 without drainage** and the gas will expand to 1 ml (Fig. 10.**10b**). The most you can inject into an eye without draining subretinal fluid is about 0.3 ml of gas. This is because the eye can expand by approximately 5% of its volume and 5% of a 6 ml eye is 0.3 ml.

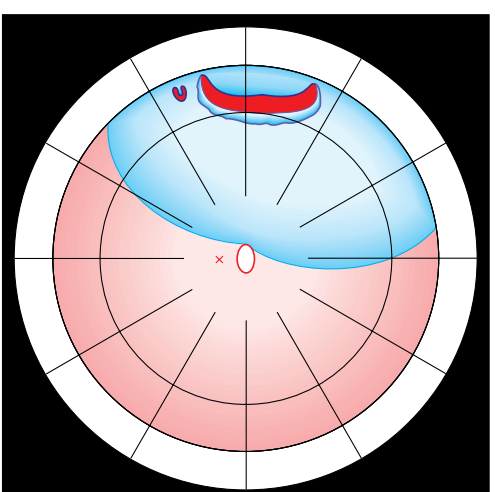


Fig. 10.**10a** 2-quadrant detachment with a large tear and a small horseshoe tear in the area of the superior rectus muscle: The macula is attached and the patient has full visual acuity. The 2 tears are too large in extent for a temporary balloon buckle, and 2 radial sponges in the area of the superior rectus muscle might cause diplopia.

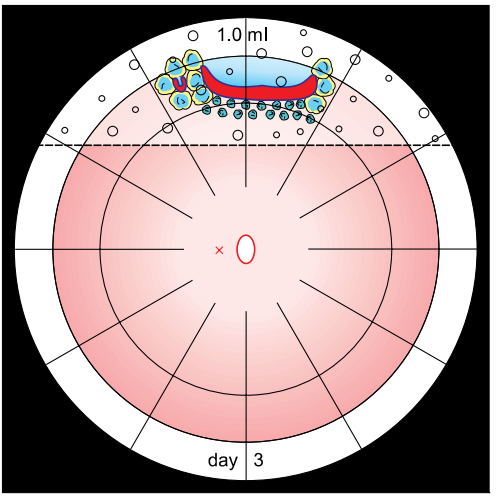


Fig. 10.**10 b** 0.3 ml of C_2F_6 was injected without drainage and after expansion at day 3, the gas has a volume of 1.0 ml. The patient was advised to sleep elevated at least 45° to cover the tears. After reattachment, the posterior edge of the large tear was secured with laser lesions; the lateral edges up into the pars plana and the smaller horseshoe tear were treated with cryopexy prior to gas injection. The half-life of C_2F_6 ranges between 10 and 12 days which is a sufficient time for an adhesion to develop.

? If you inject more than 0.3 ml of gas without prior decompression, what will happen?

- Intraocular pressure will rise enough to close the central retinal artery.
- Therefore, whenever you inject a gas, be sure to look at the **central retinal artery for patency. It can be a fatal error not to know that you have closed off the central artery, because the patient may lose light perception** if the closure persists.

Consequently, every time you inject gas into an eye, examine the central artery for perfusion.

- By and large, **0.2 ml of gas is safe and 0.3 ml** is usually possible if you decompress the eye a little before injecting.
- **For a larger volume to inject without prior drainage**, more decompression can be obtained by applying the **balloon-gas procedure,** which will be discussed below (see Chapter 10.5, pp. 159–166).

A question you might raise:

? How could it have been possible to inject a larger volume of gas (e.g., 0.6 ml), without closing off the central artery, in an emmetropic eye and without prior drainage of subretinal fluid or decompression by the balloon-gas procedure?

- Reflect!
- The **gas had escaped** via the connection between the syringe and the millipore filter or at the injection site. The explanation is as easy as this.

Injecting 0.3 ml of gas is about the same as injecting 0.3 ml of water. The effect of gas compression is insignificant, the intraocular pressure will rise either to 50 mmHg or more. This can be understood if you compute the change in volume in relation to absolute pressure: You are really going from 780 mmHg to 830 mmHg, and the reduction in volume 780/810 x 0.3 ml is insignificant.

? What is important?

- **If you want *1 ml of gas* as tamponade in an eye during the period a retinal adhesion will develop,**
- **Inject *0.3 ml of C_2F_6* without drainage.**
- **In 48 to 72 hours there will be 1 ml of gas** for a tamponade.

This technique is used for pneumatic retinopexy [21], a method for treating an uncomplicated detachment without drainage of subretinal fluid, which will be discussed below (see Chapter 10.7, pp. 256–258). However, as already explained, the morbidity of the intraocular gases does not, in our opinion, justify their use for uncomplicated detachments.

Another feature of the gases is that they provide a better tamponade than silicone oil or a liquid perfluorocarbon.

? Why do the gases provide a stronger tamponade effect than silicone oil?

Because the *buoyant force* of a bubble of gas is *16 to 17 times more than that of silicone oil.*

Also, recall, the maximal buoyant effect of a gas bubble is at its apex. This means that you should center your bubble over whatever you want to tamponade to obtain a maximal tamponade there.

10.3.2.2 Complications

Lens

The gases will interfere with the metabolism of the lens and cause a posterior subcapsular cataract, if they cover more than 1/3 of the lens. A cataract will begin to manifest itself within 24 hours. At that time you might see a faint crystalline effect within the posterior lens capsule. In 3 days it will become a significant posterior subcapsular cataract in most patients.

This phenomenon was studied in a rabbit model [32]. It was found that if only 1/3 of the lens was covered with gas, you will sometimes get a superior cataract, but this usually disappears. Apparently, there is still enough transfer of metabolic products across the inferior portion of the lens capsule to prevent a cataract from forming.

Consequently, when injecting a gas bubble into the eye of a patient, remember that you do not want to cover more than 1/3 of the lens. If more gas is required, the patient has to tilt the head forward to keep the gas bubble off the back of the lens.

As a rule of thumb:
- If, after a gas operation, there is only a little cataract in a lens, it will usually diminish after some days and result in almost no opacity.
- If you cover the lens completely with a gas bubble for 4 or 5 days, it is likely to cause a permanent lens opacity.
- In the presence of a large gas bubble, if at least 1/3 of the lens is kept free of the bubble by head tilting, after 6 to 12 days vacuoles in the posterior lens might occur.
- In general, however, these vacuoles will regress in subsequent weeks.

Intraocular pressure

Assuming you inject an expanding gas into an eye with a normal outflow and the patient is positioned so that the chamber angle is

not compressed by the gas bubble, a rise in intraocular pressure is unlikely.

? What are the effects of gas on intraocular pressure during the period of expansion?

▶ As the gas expands, aqueous goes out and intraocular pressure remains unchanged.

It is a fortunate circumstance that the outflow can compensate for the expansion of intraocular gas.

Occasionally there are reports of an increase in pressure after a gas injection. This increase is rarely above 30 mmHg unless the patient has a diminished outflow.

? Glaucoma or a diminished outflow is a contraindication for the use of an intraocular gas tamponade: What about going on an airplane with a gas bubble in the eye?

▶ Examine the question in terms of absolute pressures.

At sea level, the absolute intraocular pressure is 777 mmHg and the atmospheric pressure is 760 mmHg. The difference, 17 mmHg, is the intraocular pressure as measured by a tonometer. An ascending airplane depressurizes the cabin to 564 mmHg, the atmospheric pressure at 8,000 feet, even if the plane ascends higher than 8,000 feet. A gas bubble in an eye must increase in volume by the fraction 777/581 to maintain an intraocular pressure of 17 mmHg. This is an increase in volume of approximately 1/3. If the intraocular gas bubble is not too large, the eye can accommodate the expansion.

● **The increase in intraocular gas volume during flight is partially compensated for by:**
- Scleral expansion
- Choroidal compression, followed by
- Accelerated aqueous outflow.

Here you see what actually happens, depicted in a diagram (Fig. 10.**11**). The lower line represents the change in atmospheric

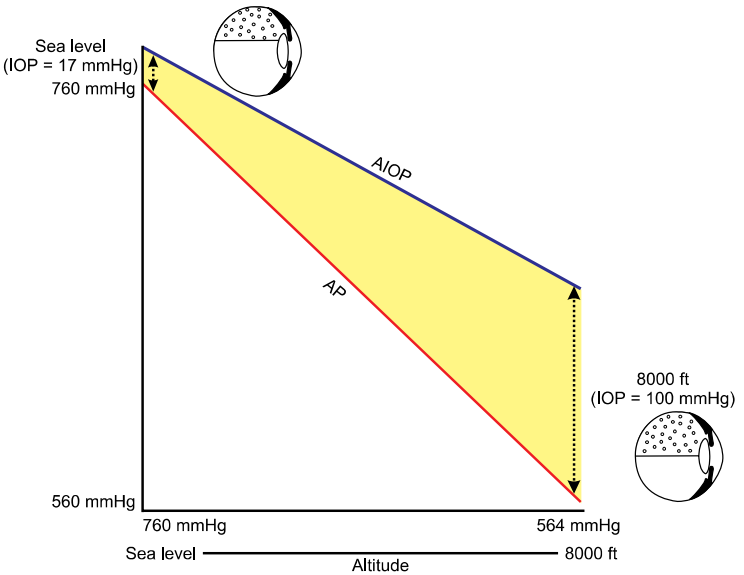
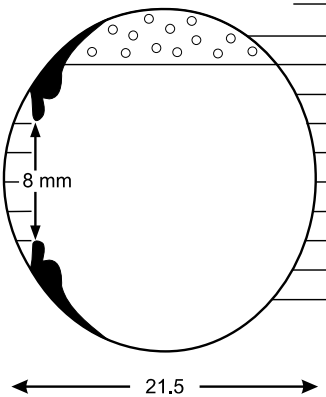


Fig. 10.**11** Effect of an ascent being on an airplane from sea level to 8,000 feet on an eye containing a gas bubble too large to be compensated for. The absolute intraocular pressure (AIOP) has fallen, but not as rapidly as the fall in atmospheric pressure (AP). As a result, the intraocular pressure (IOP) has increased (see yellow area) [33].

pressure from 760 to 564 mmHg, the change from sea level to 8,000 feet. The top line represents the change in absolute intraocular pressure for an intraocular gas bubble that is about 25% of the ocular volume. In the example the absolute ocular pressure falls, but not as rapidly as the atmospheric pressure. The difference between the 2 lines that increasingly separate is the increasing intraocular pressure. In this example, intraocular pressure rises above 80 mmHg and is symptomatic.



Disk diameters from top of disk	Volume (ml) aphake	Volume (ml) phake	Volume (%) average
5	0.17	0.15	4
4	0.39	0.33	8
3	0.75	0.61	15
2	1.27	1.00	25
1	1.90	1.45	37
0	2.60	1.95	50
-1	3.31	2.46	63
-2	3.93	2.91	75
-3	4.46	3.30	85
-4	4.81	3.58	92

Fig. 10.**12** Chart showing the volume of an intraocular gas bubble in ml and the percentage of total volume measured ophthalmoscopically in disk diameters (dd) of the meniscus above the top of the disk. When the meniscus of the bubble is **4 dd above the top of the disk, the fill is less than 10%** (shaded in gray). 10% is the maximal volume with which a patient can travel safely on an airplane.

Therefore, let me make specific recommendations:

? How much gas can a patient have in the eye and still go on a commercial airplane?

▶ **Approximately 10% of the ocular volume, which is about 0.6 ml.**
- The expansion of 0.6 ml can be compensated for by outflow and will not cause pain providing the patient has a normal outflow.

? How will you know that the patient has only 0.6 ml of gas or less in the eye?

▶ **To determine this in your office, there is a chart** from which you can easily read the volume of gas in a patient's eye in relation to the **level of the gas meniscus at the *retina*** (Fig. 10.**12**).

However, most doctors would measure the volume of a gas bubble by looking at the level of the meniscus in the pupil. This observation is prone to error. Further, if the meniscus of the gas bubble is within the pupil, the bubble is at least 25% of the ocular volume and too large. If the gas bubble is in the middle of the pupil, the eye has a 50% fill.

? What is a better way to determine the level of the meniscus of a gas bubble in the eye?

▶ Sighting it with indirect ophthalmoscopy to determine the level of the **meniscus of the gas bubble at the retinal surface** [29] **and to measure it in disk diameters (dd) above the *top of the disk:***
- **If the meniscus of the gas bubble is at the top of the disk, the patient has a 50% bubble.**
- **If the gas bubble is *4 dd above the top of the disk*, the patient has a bubble that is *less than 10%* of the ocular volume** (Fig. 10.**12**).

Consequently, when your patient asks:

? Can I go on an airplane with the gas in my eye?

▶ You will say:
"Let me examine your eye, dilated."
Measure the level of the meniscus of the gas bubble in dd above the disk.

? If it is less than 4 dd in a normal size eye, what will you do then?

▶ You will say:
No, you cannot go on the plane, but come back in a couple of days.
- ***When the meniscus of the bubble reaches 4 dd above the top of the disk, intraocular volume is less than 10%.***

Then you will say to the patient:
"Yes, you can fly on a plane."

Vitreous

- Gases affect the vitreous because they break down the blood aqueous barrier. **Within 24 hours after gas is injected, cells and a protein flare appear in the vitreous.**

You will recall the facts we addressed when we were talking about nondrainage.

- **Nondrainge provided the following advantages:**
  - You do not have to decompress the eye prior to sewing on a buckle and, as a result, you will not have the complications of drainage.
  - Since you do not abruptly decompress the eye, there will be no break down of the blood aqueous barrier with an attendant influx of protein and cells into the vitreous.
  - **In addition, bear the following in mind for the gas operation:**
    - **Every intraocular injection of gas is noxious for the vitreous because it causes a vitreous reaction that is independent of the gas injected.**

Constable demonstrated this in experiments almost 25 years ago [34]. He injected air and nitrogen, the gases available in those days, into the vitreous; both gases really caused the same reaction. The perfluorocarbon gases have no special quality, only that they are less soluble. Therefore:

- **Gases cause a break down of the blood aqueous barrier if they remain in the eye longer than 24 hours.**

? What can you observe 24 hours after you have injected gas into the vitreous?

1. If you look with the slit lamp, you can already detect a Tyndall effect in the vitreous. In another 12 to 24 hours, you will even see **cellular infiltration** of the vitreous. The cellular infiltration is not desirable for the vitreous.

Besides the cells in the vitreous, there is another, even more serious effect that a gas injection will cause.

2. If there is a substantial amount of gas in the eye, it will **liquefy the vitreous** (Fig. 10.**13**) [35]. We could show that a 90% displacement of the vitreous by gas causes a **diminished concentration of hyaluronic acid by 18.6%.** Lesser displacements of vitreous caused a lesser loss of hyaluronic acid, but the differences were not significant [36].

— ***The loss of hyaluronic acid after intraocular gas causes a diminished viscosity of the reconstituted vitreous.***

In this context you should recall what will happen to an eye when it becomes aphakic. The eye will lose about 1/3 of its hyaluronic acid content. If you use a gas compression in an eye, you are causing a somehow similar effect on the vitreous.
But when you inject gas into the eye, there is another, worse side effect. You can see this in an eye in which the vitreous was compressed by gas (Fig. 10.**14**). At first we thought that the gas compression might have induced a vitreous detachment.

3. After gas compression cortical vitreous can be seen densely packed over the pars plana and at the **back of the lens** (Fig. 10.**15**). This will persist unless it is removed with a vitrector. The same condensation of cortical vitreous can be seen **over the disk** [37].

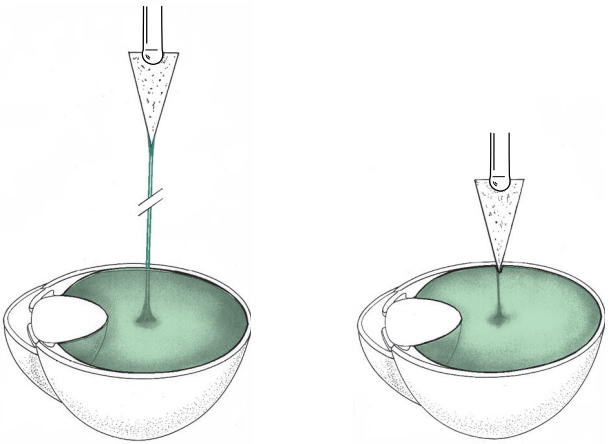


Fig. 10.**13** *Left:* The vitreous of an untreated eye is tested for viscosity. A cellulose sponge draws a strand for 10 to 12 cm; *the untreated vitreous is viscous. Right:* The vitreous after a gas compression. A cellulose sponge draws a strand for only 1 to 2 cm before it parts; the *reconstituted vitreous is watery* [35].

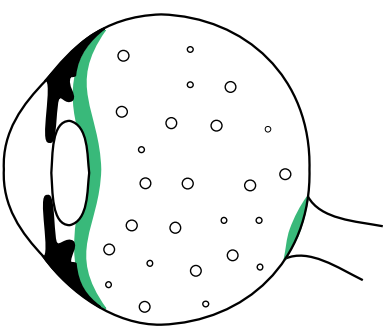


Fig. 10.**14** A gas-filled vitreous cavity with compressed vitreous structures over the disk, the pars plana, and at the back of the lens.

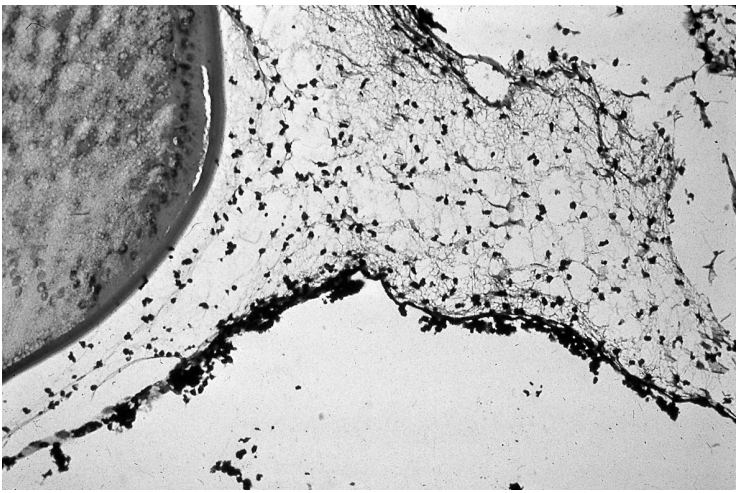


Fig. 10.**15** Histological section of the condensed vitreous anteriorly at the edge of the lens in a gas-filled rabbit eye. Note the cells within the vitreous [37].

After the gas has disappeared, the reconstituted vitreous appears optically clear, but only by ophthalmoscopy. With slit lamp biomicroscopy you can see cells and a protein flare. Sometimes the **reconstituted vitreous, altered after a gas compression, has a convection current** (Fig. 10.**16**).

? What does this mean?

- You will recall the findings in an eye after a pars plana vitrectomy with the vitreous replaced by balanced salt solution.
- Also in the reconstituted vitreous you can observe that the cells behind the lens are descending and probably ascending at the posterior retina. This is caused by an intraocular convection current, which is possible because there are practically no vitreous structures within the vitreous cavity.

The cortical vitreous of a monkey's eye, that has not been compressed by a gas bubble, looks like a rattan mat on the surface of the retina (Fig. 10.**17**). The mat appears to be several layers thick.

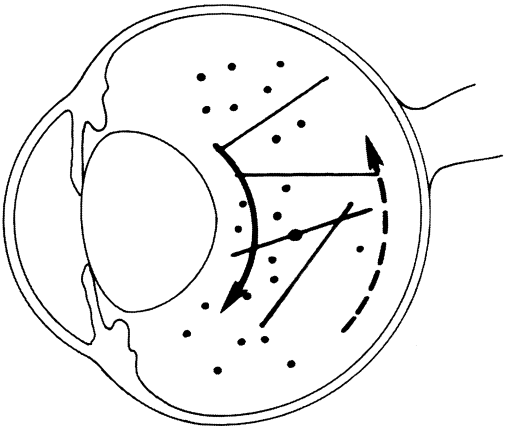


Fig. 10.**16** A slit lamp examination of the *reconstituted vitreous* (rabbit eye) reveals cells in a convection current [37].

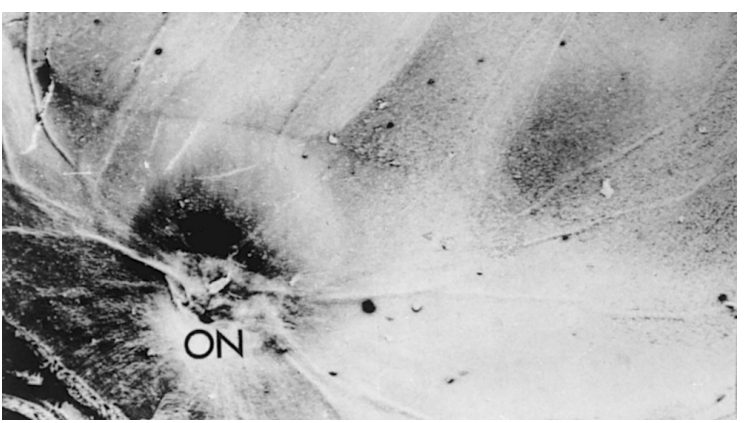


Fig. 10.**17** The posterior pole of a monkey eye, not treated by a gas injection (control). In the center is the optic nerve (ON). Note the smooth appearance of the retinal surface [38].

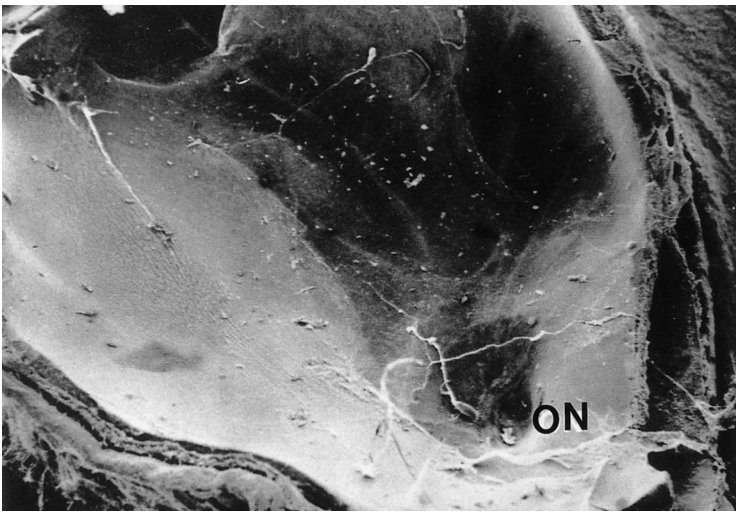


Fig. 10.**18** The posterior pole of a monkey eye 6 weeks after gas injection. The lamellae of the cortical vitreous are torn; 3 levels of lamellae can be recognized as well as areas of bald retina. ON = optic nerve [38].

In the next Figure (Fig. 10.**18**) you see the retina of a monkey that has undergone a gas compression with C_3F_8. The vitreous, in particular the cortical vitreous, is severely disorganized [38]. In some areas it is torn and in other areas there are strips of cortical vitreous. Three layers of disorganization in the cortical vitreous are evident (Fig. 10.**19**).

4. After a gas compression, the **cortical vitreous** on the surface of the retina is **torn and in total disorganization** (Fig. 10.**20**).

– What you have just seen is in a monkey retina, treated with gas.
– **You can imagine that when you inject gas into a patient's eye, you probably induce similar changes.**

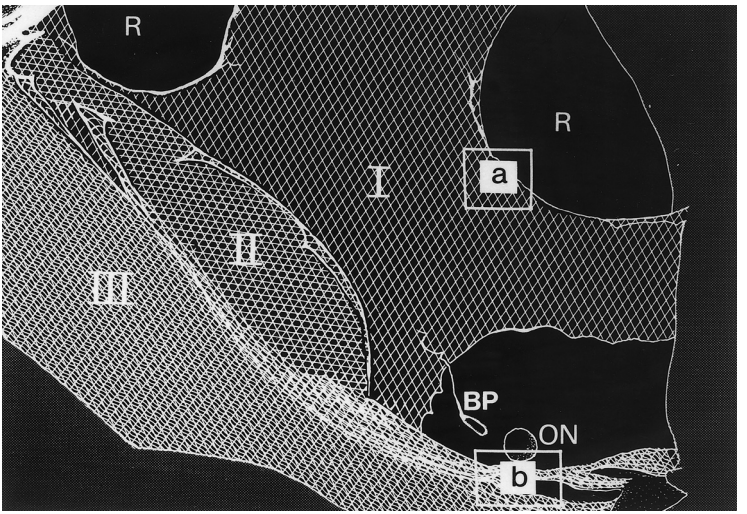


Fig. 10.**19** Schematic representation of the lamellar pattern seen in Figure 10.**18**: 3 levels of lamellae (I, II, III) are defined. R = bald retina, ON = optic nerve, BP = Bergmeister's papilla. Box [a] depicts transition from lamellar area to bald retina. Box [b] corresponds with Fig. 10.**20**.

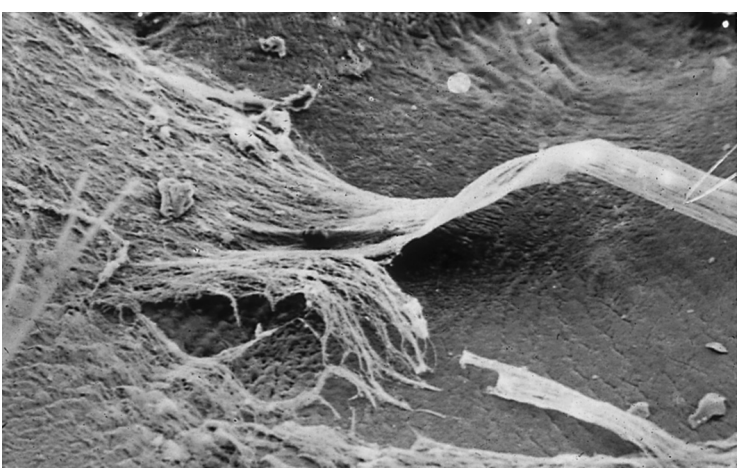


Fig. 10.**20** Magnification of box [b] in Figure 10.**19** depicting a thick membrane-like structure. The collagen fibers are oriented in the long axis of the membrane. A relatively bald retina lies beneath it [38].

? With the previous 4 facts in mind, you may be more able to understand that an intraocular gas bubble might induce a cascade of biological over-reactions: Why?

5. The combination of compressed remnants of cortical vitreous on the retinal surface and cells in the vitreous after intraocular gas will provide conditions for the following course:
— The development of PVR and new tears.

Consequently:

6. The complications at the vitreoretinal interface after an intraocular gas injection are significantly greater than those after an extraocular tamponade.

10.3.2.3 Conclusion

The use of gas as a tamponade for a retinal break has the following *advantages:*

- The injection of gas into the vitreous implies a minimal procedure.
- Another advantage of the perfluorocarbon gases is that they have an expansion potential and, as a consequence, make feasible a nondrainage procedure. Depending on the length of the carbon chain, the gas can acquire different volumes that can be pre-calculated and selected for various retinal problems.
- In addition, the perfluorocarbon gases provide a spectrum of longevity for an intraocular tamponade, extending from days to weeks.
- Another advantage of an intraocular gas bubble is that it leaves the eye spontaneously by going into solution. As a result—in contrast to silicone oil—a second procedure is not necessary to remove the gas.
- But most important of all is the buoyancy of an intraocular gas bubble. In this respect it is superior to any other intraocular tamponade: **The buoyancy of a gas bubble is 16 to 17 times greater than that of silicone oil.**

- In contrast to fluids, which also can be used as replacement for lost volume after drainage, the gas bubble also serves as an optimal tamponade because, due to its surface tension, it does not enter the break.

However, there are *undesirable side effects* to an intraocular gas bubble:

- Whenever you decide upon a gas tamponade, you should keep in mind the biological and histological changes it will induce. There will be a break down of the blood aqueous barrier, an infiltration of cells into the vitreous after 1 to 2 days, and a compression of torn and disorganized cortical vitreous on the surface of the retina.
- **In this way a gas injection might initiate an irreversible biological process in an uncomplicated detachment:**
  - **The development of PVR in 4%**
  - **New breaks in 15% of eyes [23] (see Chapter 11.3, pp. 275–279).**
- **As a result, if you have to treat an *uncomplicated detachment*, in which neither the size nor the location of the break presents a problem for its tamponade;**
  - ***Segmental buckling*** (sponge, balloon) ***without drainage, an extraocular approach, provides the procedure with a lesser morbidity.***
- Another complication which might develop when using an intraocular gas bubble is the development of a cataract.
  It can be prevented if 1/3 of the lens is kept free of the gas bubble. If more gas is needed then the patient will have to tilt the head to provide an adequate metabolic exchange via the back of the lens.

? The following complication, an increase in intraocular pressure, should not occur when using an intraocular gas bubble. How will you prevent this complication?

- Before injecting an undiluted perfluorocarbon gas, make sure the eye does not have a diminished outflow.
- After injecting an expanding gas bubble, make sure that the central artery is patent and the patient's head is positioned so that the chamber angle will not be compressed.

- A patient with **gas in the eye cannot enter an airplane until the residual gas bubble has a volume of 10% or less.**
  Be certain that the meniscus of the bubble is at least **4 dd above the top of the disk.**
- A patient with gas in the eye **cannot have general anesthesia with N_2O.**
  This warning has also to be forwarded to any nonophthalmic surgeon your patient might go to.

- **For all of these reasons, we think that the use of an intraocular gas tamponade should be reserved for retinal detachments with tears not suitable for external buckling.**
- But if the gas technique succeeds in reattaching these difficult detachments, it may represent the next level of a minimal operation with a minimum of morbidity in comparison to other more invasive and more extensive alternatives.

10.4 Instrumentation and Surgical Technique

Hilton and Grizzard [21], Tornambe et al [39], and others inject gas into the vitreous in an outpatient setting or at the bedside of a recently operated patient. However, we recommend that an intraocular gas injection should be done under sterile conditions in the operating room.

10.4.1 Preoperative Phase

? What do you have to prepare in the operating room before starting with the gas injection?

Check whether:
- The special gas you have selected for use is still available, i.e.,
- The tank contains enough gas for the scheduled operation.

Fig. 10.**21** Set of gases, desirable in an operating room for retinal detachments: Xenon (short-acting gas to replace volume, e.g., after accidental drainage), 3 perfluorocarbon gases: CF_4, C_2F_6 (half-life of 12 days, optimal gas), C_3F_8.

The armamentarium of gases that is recommended as being available in your operating room for the full spectrum of gas surgery is demonstrated in Figure 10.**21**. To the left Xenon, a gas which does not expand; it has a very short intraocular half-life of 6 hours, and after 16 hours 90% of the gas will have left the eye [40]. Because of its short duration in the eye, **Xenon minimizes the cellular response in the vitreous and the subsequent complications.**

- **Therefore, Xenon is an optimal gas:**
  It should be available when doing buckling to restore intraocular pressure in the situation of an inadvertent perforation.

To the right in Figure 10.**21** are the 3 perfluorocarbon gases: CF_4, C_2F_6 (the optimal gas for tamponade), and C_3F_8. We no longer use C_4F_{10}.

10.4.2 Intraoperative Phase

? How do you prepare the patient's eye for a gas injection?

▶ In a similar manner to preparing for a buckle or balloon operation.

After cleaning the periorbital skin with soap and painting it with Betadine (povidone–iodine), the fornix is irrigated with a dilute Betadine solution. The face and lids are covered with an adhesive drape. The drape is incised between the lids and a wire speculum inserted.

? What type of anesthesia will you apply?

▶ No retrobulbar, but instead **topical anesthesia** (e.g., cocaine 5% or tetracaine 2%).

? Why only topical anesthesia?

▶
- **To preserve the patient's light perception** during the gas injection. In doing so, the patient can tell you the moment when light perception is fading.
- **This is essential to avoid an occlusion of the central retinal artery.**

Cryopexy prior to a gas injection will reduce the intraocular pressure to some degree. Others apply a Honan balloon at 30 to 35 mmHg to reduce intraocular pressure. More intraocular space can be obtained by inserting a parabulbar balloon prior to the gas injection and expanding it until the central artery starts to pulsate. After about 2 hours the balloon volume can be withdrawn and a volume of 0.7 ml to 0.8 ml of gas can be injected into the vitreous without prior drainage and without closing the central artery (for more details, see Chapter 10.5, pp. 159–166).

You might begin the gas procedure by placing a traction suture through the insertion of the lateral rectus muscle or the muscle closest to the intended injection site. The traction suture will help

you to stabilize the eye during the gas injection. Two sterile millipore filters are inserted into the tubing of the gas tank. The circulating nurse slowly opens the outlet valve of the gas tank until the surgeon can hear the soft flow of the gas (Fig. 10.**22a**). After that, he or she inserts a 2 ml syringe with 2 sterile millipore filters (Fig. 10.**22b**).

Fig. 10.**22 a** Preparation of gas for intraocular injection: Open the outlet valve of the gas tank until the surgeon can hear the flow (more like a soft whistle) of the gas.

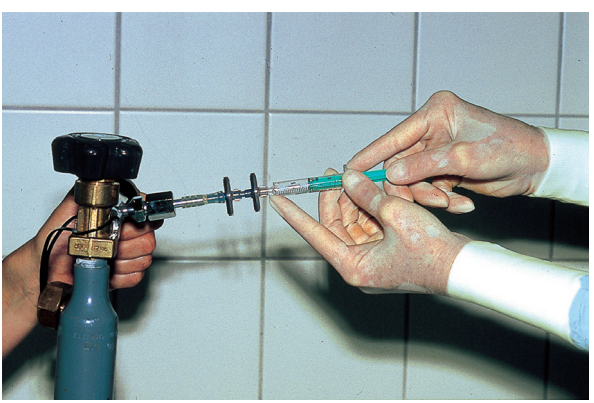


Fig. 10.**22 b** Insert a 2 ml Luer syringe with 2 sterile millipore filters.

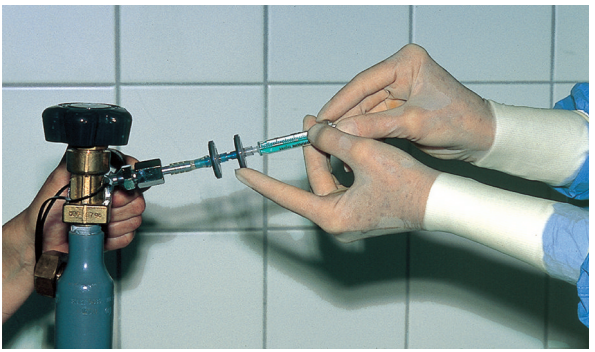


Fig. 10.**22 c** Let the slowly outstreaming gas displace the plunger of the syringe to the desired volume (do not actively withdraw the gas because otherwise air might be aspirated via the connecting parts). Repeat this to remove air that might be present in the "dead space" of tubing.

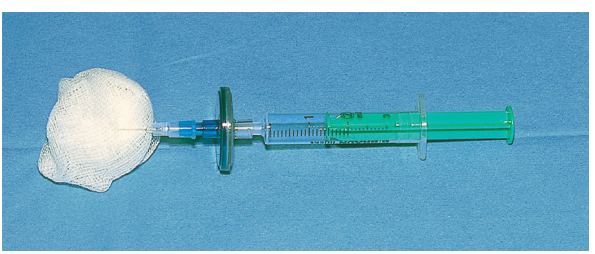


Fig. 10.**22 d** The syringe ready for intraocular gas injection: It is filled with gas, covered with one millipore filter and a shortened (5 mm) 30-gauge needle. To keep the needle sterile, it is covered with a cotton swab.

Be careful that the pressure of the outstreaming gas is not too high.

You should not withdraw the gas with the syringe, but the pressure of the outstreaming gas should displace the plunger of the syringe to the desired volume (Fig. 10.**22c**). With the syringe filled with gas, disconnect and push out a small amount of gas to clear the air present in the end of the syringe and needle (30-gauge) that you will have placed on the syringe. To keep the needle sterile and for its protection, it is covered with a cotton swab (Fig. 10.**22d**).

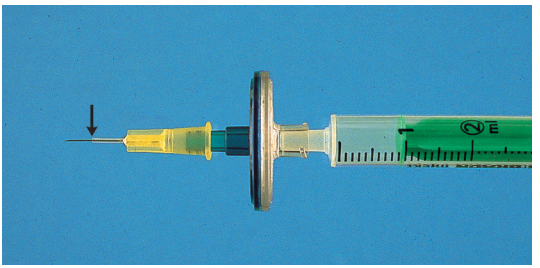


Fig. 10.**23** Shortened 30-gauge needle for intraocular gas injection: A piece of silicone tubing (see arrow) is slid over the needle to reduce its effective length to 5 mm.

? To avoid the needle penetrating the eye too deeply when injecting the gas, how should you proceed?

▶ Use a short 30-gauge needle with a length of only 5 mm. However, the commercially available 30-gauge needles have a length of 12 mm.

? How can such a needle be shortened?

▶ Slide a piece of silicone tubing (7 mm long) over the needle to obtain an effective length of 5 mm (Fig. 10.**23**).

? Where should you enter the eye with the needle to avoid injury to the lens or retina?

▶ After cauterization, enter the eye 4 mm from the limbus (emmetropic eye) and direct the needle towards the center of the vitreous.

? How should you perform the injection itself?

▶ It is important that the gas injection is done with the tip of the needle under constant observation.

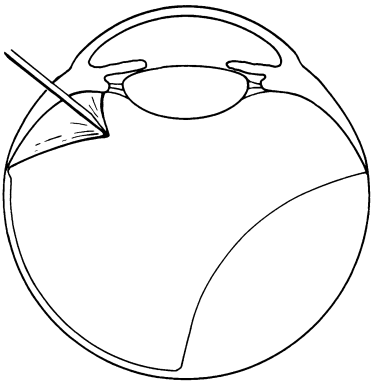


Fig. 10.**24** Intraocular injection of gas via the pars plana: To prevent the complication of "gas under the retina," the tip of the needle has to be through the ciliary epithelium and through a proliferative membrane that might be adherent to the internal surface of the ciliary epithelium. If necessary, drill with the tip of the needle through the membrane, inject a small gas bubble and observe whether the bubble ascends towards the back of the lens. Only then can you start with the intraocular gas injection.

? Why?

▶ To be certain that the tip of the needle has gone through the ciliary epithelium and into the vitreous and **is not under a transparent proliferative membrane** that might be adherent to the internal surface of the ciliary epithelium (Fig. 10.**24**).

? Why is this so important?

▶ Because if gas is injected under a membrane, the gas will break through the ora serrata and enter the subretinal space:
Gas under the retina is a serious complication!

● To avoid this complication of gas injection, observe the needle tip and look for a membrane tented on the needle tip. If it is present, drill through it by rotating the syringe and the tip of the needle. Then inject a small gas bubble and observe whether the bubble ascends towards the back of the lens.
— If this happens, you are through the membrane.
— You can start the gas injection.

A single large gas bubble is preferable because you can visualize the retina through it and perform laser treatment.

? But how do you obtain a single large gas bubble instead of so-called fish eggs?

▶ To begin with, rotate the eye so that the injection site is at the highest level when you inject the gas. Be certain that the assistant keeps the tip of the **needle within the gas bubble for the duration of the injection.** If needed, the assistant might have to withdraw the tip of the needle for 1 to 2 mm, however, only under ophthalmoscopic control by you.

? When do you stop the injection?

▶ **Before the central artery is closed:**
- Inject the gas very slowly. Your patient, having been informed to watch out for the moment that light perception will dim, will suddenly say: **"It's getting dark."**
- At that very moment you will stop your injection. **During a gas injection the interaction between patient and surgeon is vital to prevent the central artery from closing.**
- This is only possible if the gas operation is done under **topical anesthesia.**

? What should be done, if you have injected too much gas, the central artery is closed off, and the patient's light perception gone?

▶ **Reflect and do not over-react:**
- At this point many surgeons would apply a paracentesis, but this would risk vitreous incarceration in an aphakic eye or would be ineffective.
- Instead, with the needle still *within the gas bubble*, let the assistant aspirate under your ophthalmoscopic control until the patient says: **"Light is coming back."**
- Then withdraw a little more of the gas and re-inject it during the removal of the needle from the eye to **avoid the risk of vitreous incarceration in the injection site.**

● **As a rule of thumb:**
The **central artery** should not be closed off for longer than 5 minutes;
7 minutes should be a rare exception.

However, it should be mentioned that some surgeons permit up to 10 minutes.

Experiments on monkeys demonstrated that it is possible to close the central artery for 99 minutes and still retain a functioning retina. But these were young animals with no retinal degenerations or retinal detachment. This is the reason why we try to close off a central artery for no longer than 5 to 7 minutes.

? **How should you withdraw the tip of the needle without gas bubbles escaping at the injection site?**

▶ Prior to removal of the needle, you turn the injection site from the superior to a more inferior position by the one traction suture. During the moment of withdrawal of the needle you might close up the injection site in addition with a wet Q-tip.

To be certain again that the central artery is open, examine it after the needle is withdrawn.

? **The injection of an expanding gas under general anesthesia requires special precautions: Why?**

▶ **Nitrous oxide (N_2O), a soluble anesthetic gas,** will increase the gas bubble volume during general anesthesia if the patient has SF_6, for example, in the eye.

● – **N_2O** which is 100 times more soluble than SF_6 will **cause an expansion of a SF_6 bubble by 3 times** its volume **in 20 minutes**.
– As a result, **N_2O should be avoided as a general anesthetic** in patients who have an intraocular gas bubble.
– It is your responsibility to inform the anesthesiologist about this risk.

Also forward this warning to any non-ophthalmic surgeon your patient might go to when there is **still gas in the eye.**

- **Let us summarize the complications you might be confronted with when performing a gas injection:**
  - **Avoid injury to the lens** by directing the tip of the needle towards the center of the vitreous, and use a 30-gauge needle of 5 mm in length or one shortened by a silicone tube over part of it.
  - **Avoid injecting gas under a ciliary body membrane and the retina** by ascertaining that the first small gas bubble from the tip of the needle ascends within the vitreous. If a membrane is present, drill through it with the tip of your needle before injecting.
  - **Avoid the formation of fish eggs,** i.e., stabilize the tip of the needle and keep it within the gas bubble during the injection.
  - **Avoid closing off of the central retinal artery,** i.e., carry out the procedure under **topical anesthesia** and inform the patient to alert you when light perception is fading.
    After the injection of 0.3 ml of gas you should check the central retinal artery for pulsation, because 0.3 ml is the maximal volume to be injected without drainage unless there has been a preceding decompression maneuver (e.g., balloon–gas procedure).
  - **Avoid the escape of gas bubbles during withdrawal of the needle,** i.e., rotate the injection site from a superior to a more inferior position.

10.4.3 Postoperative Phase

For the patient with a gas bubble in the eye, especially an expanding gas,

- **Correct postoperative positioning is mandatory to avoid:**
  - **Closing off of the anterior chamber angle**, and thus causing an abrupt rise in intraocular pressure.

- **Passage of gas under the posterior edge of a giant tear** until the edge is reattached by a special maneuver (see Chapter 10.6.1, pp. 167–212).
- **Avoid allowing more than 1/3 of the lens to be covered by the gas** bubble. Alternatively, if a larger gas bubble is present, provide a metabolic exchange via the back of the lens by positioning the patient's head forward.

Otherwise you might end up with lens opacities that preclude observation of the retina and subsequent laser treatment. **Eye drops** are administered postoperatively, i.e., an antibiotic and atropine 1% (no ointments!).

? Why only *eye drops* postoperatively?

▶ Because in a patient with gas in the eye the cornea should be clear and ready for a fundus examination at any time.

? We never double patch a patient with gas in the eye: Why?

▶ To be certain that the patient can control the position of the head.

? When does the largest expansion of gas occur and thus the greatest threat of glaucoma?

▶ During the first 24 hours, but
maximally at 6 to 8 hours postoperatively.

? How to check for a serious rise in intraocular pressure during the hours after surgery?

▶ **An easy and reliable method is:**
- Ask the nurse to flash a light into the patient's eye every 2 hours until the next morning. If the patient confirms light perception, the artery is open.

- The alternative would be to measure intraocular pressure with applanation several times during the night.

In observing this regimen, in all of the gas operations performed in the last 25 years no abrupt rise in ocular pressure went unnoticed. In addition, I would like to mention the fact that during the first days after the gas operation the patients who required special positioning of the head were closely monitored either by a relative or by a nurse. In this way we avoided the most serious complications, such as glaucoma or gas under the retina (e.g., in a giant tear).

10.5 Balloon–Gas Procedures: Basic Procedure and Extended Procedure

10.5.1 History

The balloon–gas procedure with its 2 versions, described by **Kreissig in 1986** (41), is another step towards minimal surgery. It came about as we used the expanding-gas operation without drainage more often, for giant tears, posterior holes and multiple tears at different latitude. The problem was that for these difficult detachments we needed to inject a bubble of gas larger than 0.3 ml.

- Therefore, if we still wanted to apply a gas of a shorter longevity, such as CF_4 or C_2F_6, but at the same time combined with a smaller expansion potential (by 2 and 3.3 times respectively), **it would be necessary to:**
  - **Either drain** subretinal fluid again to create sufficient space for a larger gas injection
  - **Or perform a second gas injection** after the intraocular pressure returned to normal.

Our experiences with the balloon operation suggested that it was possible to obtain more intraocular space for the gas injection if we first compressed the eye by expanding a balloon in the parabulbar space. A similar ocular compression is obtained with a Honan balloon which has a minimal effect for a subsequent gas injection. Therefore, integrating the Honan balloon into the gas operation did not prove beneficial.

? Why?

- The Honan balloon has to be removed prior to surgery to obtain access to the eye.
- The induced minor hypotony cannot be used as needed during the gas injection.

Consequently, it crossed our mind to instead decompress the eye prior to the gas injection with a parabulbar balloon inserted under sterile conditions, leaving it in place during the gas injection, and using the obtained hypotony during the gas injection to compensate for the increase in intraocular pressure. The volume of the balloon could be withdrawn as the intraocular pressure increased. This is the principle of the balloon–gas procedure [42].

With the balloon–gas procedure internal drainage is affected in 2 steps:

- Ab **externo** by ocular compression with the elastic balloon.
- Ab **interno** by expansion of the perfluorocarbon gas.

As result, a larger intraocular gas bubble can be injected without drainage or prior vitrectomy, and after expansion a larger gas tamponade is available.

Basic balloon-gas procedure: 1 purpose (Fig. 9.**33**, p. 91)

? What are the advantages of the *basic* balloon–gas procedure?

- A larger intraocular volume of gas can be injected without prior drainage of subretinal fluid or vitrectomy.
- A gas with a smaller expansion potential can be selected.
- Therefore, the injected gas will have a shorter intraocular duration, and there will be fewer complications in the vitreous and at the vitreoretinal interface.
- **A 2nd injection of gas is not needed.**

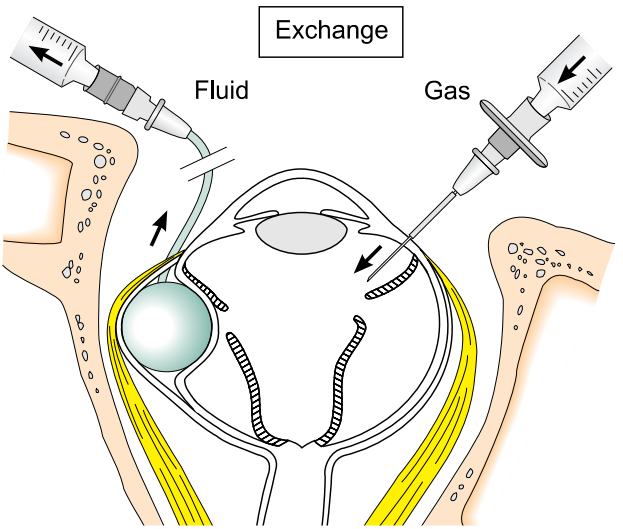


Fig. 10.**25** Diagram of the *extended* balloon–gas procedure: A kind of "fluid–gas exchange" is performed by withdrawing fluid from the preplaced balloon buckle (positioned beneath an additional break as tamponade) and replacing its volume simultaneously with an intraocular gas injection. With this procedure the tamponading effect is increased: It provides a tamponade *ab interno* by the gas bubble and a tamponade *ab externo* by the balloon buckle.

▶ **Extended balloon-gas procedure: 2 purposes** (Fig. 10.**25**)

? What are the advantages of the *extended* balloon-gas procedure?

▶ In addition to the listed advantages of the basic procedure,
- The resulting balloon buckle can be used at the same time as a **tamponade ab externo**, e.g., for an additional tear apart from the tear that requires the gas tamponade **ab interno**.
- This additional buckling of a break by the balloon indentation enables the **use of a gas bubble further decreased in volume.**

Viewing the 2 versions of the balloon–gas procedure in perspective, they can provide conditions to avoid alternative, more extensive or

morbid procedures, such as extensive buckling, a very posterior buckle, or a primary vitrectomy [27].

By using a balloon–gas procedure the larger gas bubble can be injected by a kind of **"fluid–gas exchange"** without jeopardizing the patient's light perception. The most important advantage of the balloon–gas procedures is that a 2nd gas injection into the vitreous is not required and that a gas with a larger expansion potential and longer intraocular duration is no longer needed. This results in fewer vitreous complications [43].

10.5.2 Principle of the Balloon–Gas Procedures

▶ **Basic balloon-gas procedure**

It has **1 purpose:**

1. To obtain intraocular space for injection of a larger gas bubble without prior drainage or vitrectomy.

The balloon buckle, after having been inserted into the parabulbar space under topical anesthesia, exerts a continuous external ocular compression and thus causes internal drainage of aqueous from the vitreous. After about 2 hours the compressed balloon reaches its full size. During the subsequent gas injection, as much fluid as necessary will be withdrawn from the balloon to restore the patient's light perception (hence the use of topical anesthesia). This actually represents a type of fluid–gas exchange. Due to the subsequent expansion of the intravitreal gas bubble (by 1.9 to 5 times) there will be continued compression of the vitreous meaning that "internal drainage" will continue.

- As result, the vitreous volume can be replaced by the gas bubble with no prior mechanical vitrectomy or drainage of subretinal fluid.

▶ **Extended balloon-gas procedure**

It has **2 purposes:**

1. To obtain intraocular space for injection of a larger gas bubble as tamponade *ab interno*.
2. To buckle at the same time an additional tear or group of tears (within 1 clock hour) by the inflated balloon as tamponade *ab externo*.

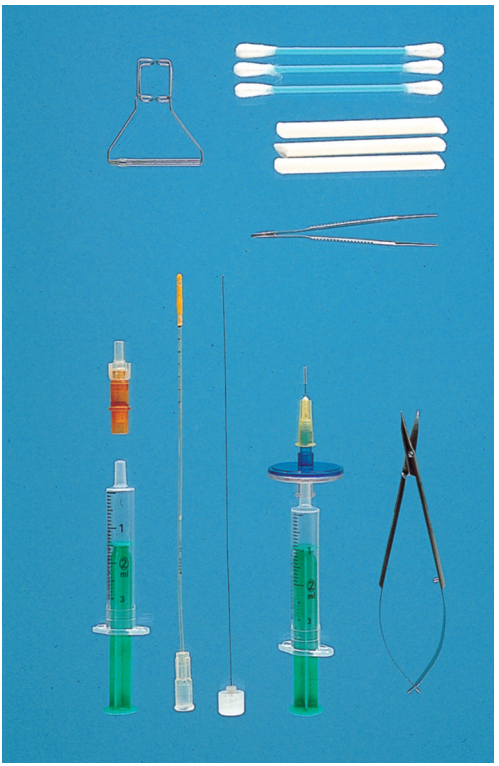


Fig. 10.**26** Instruments for the **basic balloon–gas procedure:**
To obtain intraocular space for the injection of a larger gas bubble.
Top (from the left to right): Wire speculum, Q-tips, "cigars," Bonn forceps blunt. *Bottom* (from left to right): Syringe filled with sterile water and adapter, deflated balloon catheter, withdrawn stylette, syringe filled with perfluorocarbon gas and with millipore filter and short 30-gauge needle, Westcott scissors blunt.

10.5.3 Instrumentation

The basic balloon–gas procedure does not require much instrumentation: A wire speculum, Westcott scissors, a flat forceps, a balloon with a syringe filled with sterile water, and a syringe filled with the perfluorocarbon gas, covered with a millipore filter and a short (5 mm) 30-gauge needle (Fig. 10.**26**).

If you want to apply the extended balloon-gas procedure, i.e., to buckle an additional tear at the same time by the indentation of the inserted balloon, your surgical set has to be supplemented by the instruments you would need for a balloon operation (Fig. 10.**27**).

10.5.4 Surgical Technique

As the expanding-gas operation, the balloon–gas procedure is performed under topical anesthesia. The conjunctiva is opened by 2 mm, about 7 mm from the limbus. The balloon is inserted into the parabulbar space to induce the oculocompression, or, if in addition a tear has to be tamponaded, the parabulbar balloon is placed exactly under the tear (see Chapters 9.4 and 9.5, pp. 9–25). The balloon is filled with sterile water until the patient reports diminished light perception. If it fits into your operating schedule, another surgery can be performed in the meanwhile, because you will have to wait for about 2 hours until the balloon has decompressed the eye and reached its full effect of indentation. About 1 hour after balloon insertion the assistant can add another 0.3 to 0.5 ml of fluid to increase the balloon volume up to 1.8 ml. Now check again the central artery for perfusion.

Then about 2 hours after balloon insertion you can prepare for the gas injection. This time the assistant injects gas, but slowly, until the patient reports a loss of light perception (for this reason topical anesthesia is used!).

? Do not panic at the loss of light perception *this time!* Why?

▶ Because this time you have the pre-placed parabulbar balloon to immediately restore the patient's light perception.

At the moment the patient reports loss of light perception, fluid from the balloon catheter is withdrawn until light perception is restored. This so-called fluid–gas exchange is repeated until 0.7 to 0.8 ml of gas has been injected into the vitreous. At the end of the balloon–gas procedure check again for light perception and check also the central artery for perfusion. It is useful to leave about 0.3 ml of fluid in the balloon.

Fig. 10.**27** Instruments for **extended balloon–gas procedure:**
1. To obtain intraocular space for the injection of a larger gas bubble as tamponade ab interno.
2. To tamponade an additional tear or group of tears (within 1 clock hour) *by the balloon buckle as tamponade ab externo.*
Top (from left to right): Silk for traction suture, wire speculum, Q-tip, "cigar," Bonn forceps blunt, Castroviejo caliper, Castroviejo forceps, pencil marker. *Bottom* (from left to right): Syringe filled with sterile water and adapter, deflated balloon catheter, metal stylette, syringe filled with perfluorocarbon gas and with millipore filter and short 30-gauge needle, Kreissig depressor, straight Barraquer needle holder, Kreissig balloon forceps (siliconized), Westcott scissors blunt.

? But why do you want to leave the balloon with 0.3 ml of fluid in the parabulbar space after you have finished the gas injection?

▶ To keep the almost emptied balloon from sliding out of the parabulbar space, because this residual balloon volume can be of benefit during the period after the gas injection:

- If a rise in intraocular pressure should occur postoperatively, the doctor on duty can withdraw some fluid from the balloon via the adapter (fixed at the patient's forehead) to lower intraocular pressure and **glaucoma can be avoided.**
  It can be as easy as this!
- If after some days the intraocular gas bubble appears to be too small, the effect of the **gas tamponade can be indirectly enlarged** by increasing the volume of the balloon buckle.
- If it becomes necessary **to inject additional gas**, this can again be done by the balloon–gas procedure: There is already a pre-placed balloon that can be further inflated and then deflated for the additional gas to be injected.

● ***But keep in mind:***
An eye which already has a gas bubble or a large extraocular buckle in place has less intraocular volume for internal drainage, i.e., there will be less space for an additional gas injection.
Be aware of this in such an eye and check the central retinal artery for pulsation after the gas injection.

Now let us return to the surgical situation. After completing the gas injection, the balloon is left in place. Special care is taken to direct the catheter away from the cornea to avoid an erosion. Only 1 eye is patched so that the patient can control the position of the head for an optimal tamponade. As with the expanding-gas operation, intraocular pressure has to be monitored postoperatively. This is done by testing the eye for light perception every 2 hours during the first 24 hours after surgery, i.e., until the next morning. *After surgery only eye drops are administered,* e.g., gentamycin and atropine 1%.

The balloon is withdrawn either when the resulting gas bubble provides a large enough tamponade or when the break, being tamponaded at the same time by the balloon, is secured by pigmented thermal lesions. The small conjunctival wound closes by itself after removal of the balloon.

10.6 Application of Expanding Gases

As previously mentioned, the expanding gases for an intraocular tamponade without drainage of subretinal fluid were not intended primarily for small tears (pneumatic retinopexy), but for tears not suitable for external buckling, i. e., large and giant tears, group of breaks at different latitude, and posterior holes.

10.6.1 Large Tears and Giant Tears

A tear larger than 70° cannot be placed on a radial pouch because the pouch would go through the disk and this is technically not possible. The only way to buckle a giant tear would be then with a circumferential buckle. However, when using such a long circumferential buckle on a giant tear, you will further increase the posterior redundancy which will result in large retinal folds. In Figure 10.**28** the giant tear has several radial folds due to a cerclage that had decreased the circumference of the globe. It is like tying a string around the waist of a shirt and causing wrinkles.

- In relation to a giant tear, the largest wrinkle or fold will be in the center of the constricted tear. Such a wrinkle or retinal fold on the posterior edge of a long circumferential buckle is called a **"fishmouth,"** and it is very likely to leak fluid vitreous into the subretinal space. This is the reason why you should not buckle a long tear with a cerclage or a circumferential buckle (Fig. 10.**29**).

▶ **The limits of external buckling (by using a radial pouch) are reached with tears 70° in circumferential extent:**

Occasionally, a retinal detachment with a giant tear is reattached by a posterior cerclage (Fig. 10.**30**). However, in the last 30 years I have

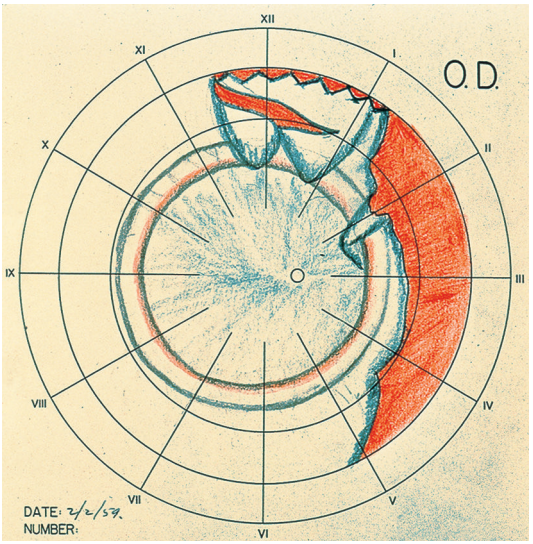


Fig. 10.**28** A detachment with a giant tear (11:30 to 5 o'clock) was treated with a cerclage. Constriction of the eye resulted in a large radial fold (fish-mouthing) at 2:30 causing posterior leakage and failure. At that time the expanding gases were not available. (Original drawing by H. Lincoff, M.D., New York in 1959.)

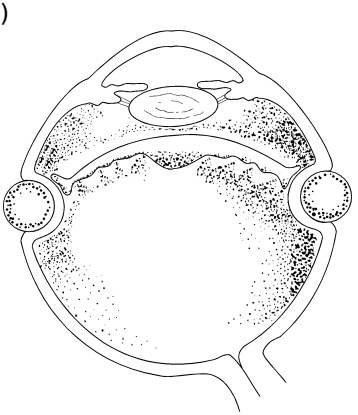


Fig. 10.**29** Constriction of the circumference of the eye by a long circumferential buckle or cerclage causing radial folds (due to redundancy of the posterior edge of the giant tear), resulting in so-called fishmouthing with leakage and failure.

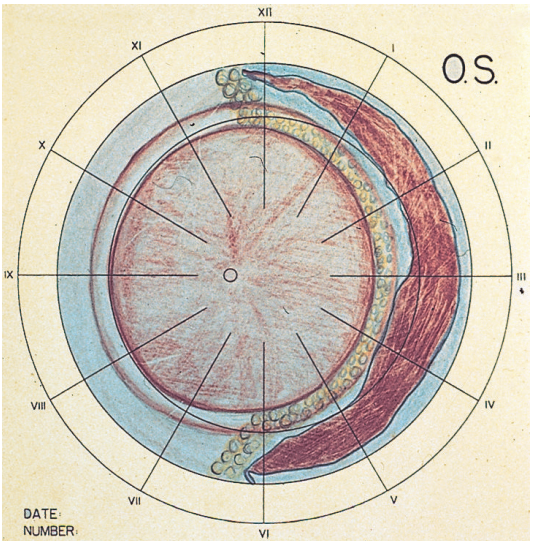


Fig. 10.**30** A detachment with a lateral giant tear from 12 to 6 o'clock was treated with a posterior cerclage after drainage, the posterior and lateral edges of the tear were secured by 2 rows of thermal lesions. Reattachment of a giant tear after cerclage with constriction without intraocular gases represents a rare exception. (Original drawing by H. Lincoff, M.D., New York in 1963.)

not seen such a miracle and I would advise you not to use a cerclage as *the* treatment for a giant tear.

A better approach to reattach a giant tear is to flatten the retina with an intraocular gas tamponade and without a simultaneous constriction of the wall of the eye, so that the retina can revert to its original position. There will be no redundancy of the posterior edge of the tear and thus no radial folds.

A practical question you might like to pose:

? Where to inject the gas in a detachment with a giant tear?

▶ Whenever possible select an area across from the giant tear or where the retina is still attached to avoid an inadvertent perforation of the detached retina.

Approaching the application of an intraocular gas tamponade step by step is recommended: Begin by treating the easier detachments, i.e., with a large tear, then with a giant tear, and finally with a giant tear with an overhanging posterior flap and additional tears.

10.6.1.1 Large Tears

▶ **When starting to use the gases for complex detachments, keep in mind the intraocular changes that will occur with a gas injection:**

- Intraocular gas causes a break down of the blood aqueous barrier, a lowering of the threshold of PVR, and morphological changes in the vitreous structure and the vitreoretinal interface.
  Consequently, it is only **when the limits with external buckling are reached that the gases are indicated** as an optimal alternative (see Chapter 12, pp. 290–298).

We use intraocular gas for an eye with a tear of more than 2 clock hours in extent (Fig. 10.**31a**). By using the basic balloon–gas procedure 0.8 ml of C_2F_6 can be injected without prior drainage of subretinal fluid (Fig. 10.**31b**). The patient is rotated around the bubble, i.e., first with the side of the eye opposite to the large tear uppermost, so that the tear is in an inferior position and not tamponaded by the gas bubble.

? Why?

▶ Because if you rotated the patient to the other side, the bubble, which is not yet expanded and too small, would pass through the tear and under the retina.

Fig. 10.**31 a** Lateral detachment with a large tear of 70° in extent. ▷
b Injection of 0.8 ml of C_2F_6 (by using the basic balloon–gas procedure) without drainage of subretinal fluid. The balloon is removed after gas injection. The patient is then rotated to the side of the large tear, i.e., now being in inferior position to circumvent gas passing through the tear under the retina. The gas bubble is still too small for a full tamponade; however, it will enlarge by subsequent expansion.

Fig. 10.**31 a**

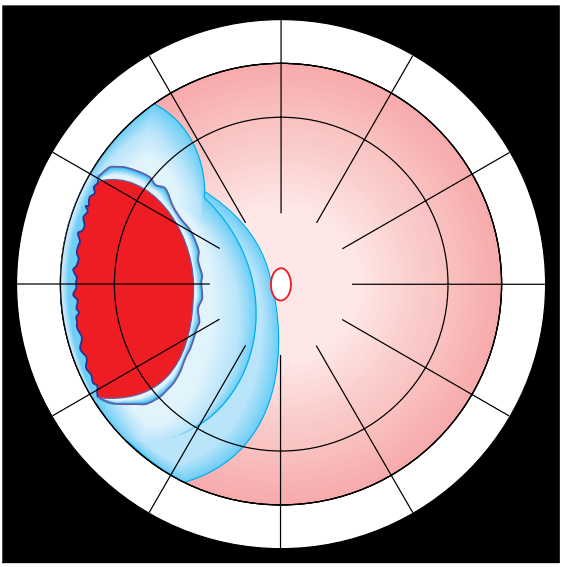
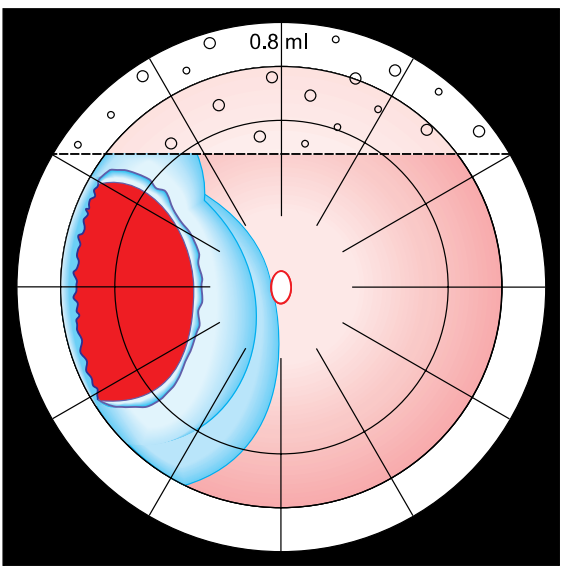


Fig. 10.**31 b**



▶ **Always rotate the patient with an intraocular bubble first with the tear away from the bubble, i.e., the tear is then in a down position across from the bubble:**

? Why?

▶ – To avoid the too small bubble sliding under the retina through the large tear.
– For this reason first let the gas bubble expand to 2.7 ml, then when the patient is rotated, the bubble will press the retina flat and slowly drive subretinal fluid through the tear and back into the vitreous.

By the 2nd or 3rd day (the retina is flattened and the posterior edge of the tear is reattached, as confirmed by ophthalmoscopy), rotate the patient over the stomach with the nose towards the mattress to a position with the bubble over the tear in maximal tamponade position. The tear is then in a superior position and fully covered by the gas bubble. The patient should remain on this side for almost all of the time.

The moment the tear is reattached, bring the patient back to the operating room and perform cryopexy of the edges of the tear up into the pars plana (Fig. 10.**31c**). You can apply laser coagulation as well. Never treat the anterior flap of a large tear, which in this detachment is very small. On day 10, the gas bubble will have receded to half volume and the lesions will be pigmented (Fig. 10.**31d**). Of course the patient needs a close follow-up, and you will explain how to check the visual field daily.

? Why?

▶ Because there is a chance that the posterior edge or the lateral edges of the tear might subsequently leak (see Chapter 10.6.5.5, pp. 247–253).

Fig. 10.**31 c** 3 days after gas injection: The bubble has expanded to 2.7 ml and the patient is rotated over the stomach, face down, to a maximal tamponade position with the bubble right over the tear. The tear is now in superior position. The reattached edges of the tear are sealed off with cryopexy lesions (no treatment of anterior flap). ▷
Fig. 10.**31 d** 10 days after gas injection: The gas bubble has receded to half volume, the cryopexy lesions are pigmented.

Fig. 10.**31 c**

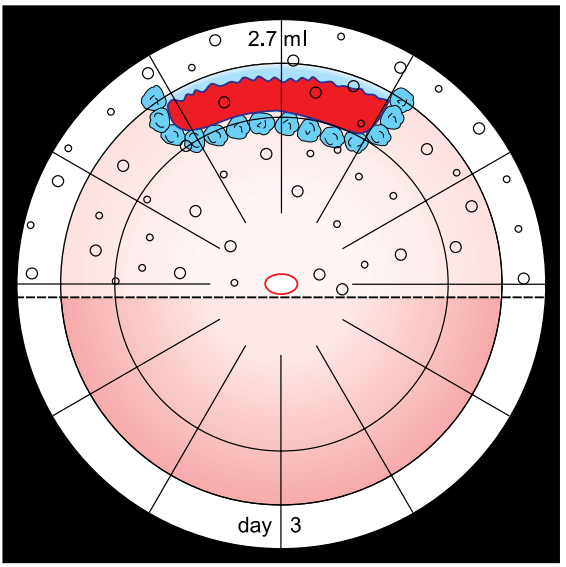
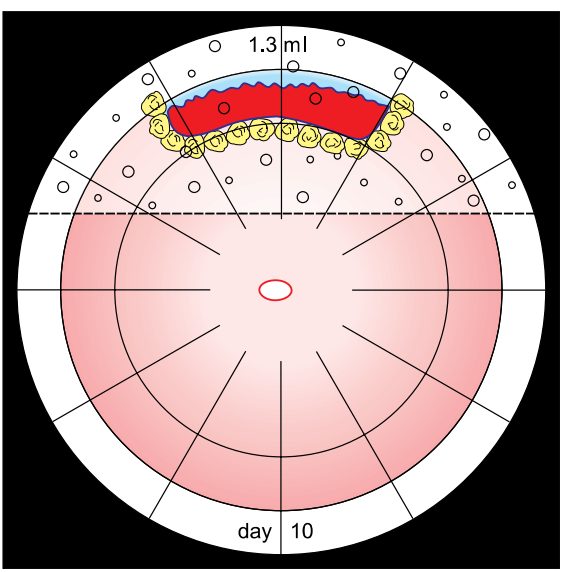


Fig. 10.**31 d**



10.6.1.2 Giant Tears and Various Gas Techniques

10.6.1.2.1 Lateral Giant Tear

The detachment with a giant tear (≥ 90° in extent) represents another degree of difficulty. The giant tear, discussed here, has an extent of 3 1/2 clock hours and the posterior edge is slightly rolled over (Fig. 10.**32a**). Since we would need a large volume of gas to tamponade this tear, we use the basic balloon–gas procedure. We place a parabulbar balloon across the giant tear and about 2 hours later under topical anesthesia a fluid–gas exchange is performed; 0.7 ml of C_2F_6 is injected, with simultaneous withdrawal of balloon fluid to preserve the patient's light perception (Fig. 10.**32b**). A residual of 0.3 ml of fluid is left in the balloon for the above-mentioned reasons (e.g., to counteract a postoperative increase in intraocular pressure). After surgery the patient is positioned with the eye on the side of the tear now in an inferior position. Overnight the gas bubble will expand. The next morning, under ophthalmoscopic control, the patient is rotated to the other side over his or her stomach, with the nose towards the mattress. The posterior edge of the tear will then be repositioned by the next morning and the giant tear tamponaded for its full length by the expanded gas bubble. If the gas bubble covers the tear adequately, the balloon is withdrawn after 3 days and the reattached posterior edge of the tear sealed with 3 rows of interrupted laser lesions (Fig. 10.**32c**). Prior to the gas injection only cryopexy lesions were applied at the anterior lateral edges of the tear extending into the pars plana. The postoperative treatment consisted of atropine 1% and gentamycin eye drops.

? Why was the rotation maneuver of the giant tear not difficult?

- Because it was a lateral giant tear and the rotation over the stomach is easy and can be done under ophthalmoscopic control.
- The posterior flap did not hang over very much. Consequently, there was no threat of the gas bubble compressing the flap against the retina.

In the subsequent weeks, radial laser bars, 1 1/2 clock hours apart and consisting of interrupted laser lesions extending from ora to the

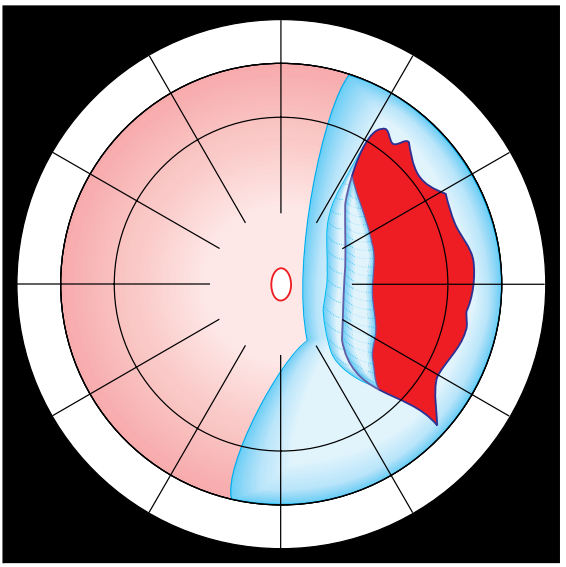


Fig. 10.**32 a** Detachment with a lateral giant tear (from 1 o'clock to 4:30) with a slightly rolled-over flap.

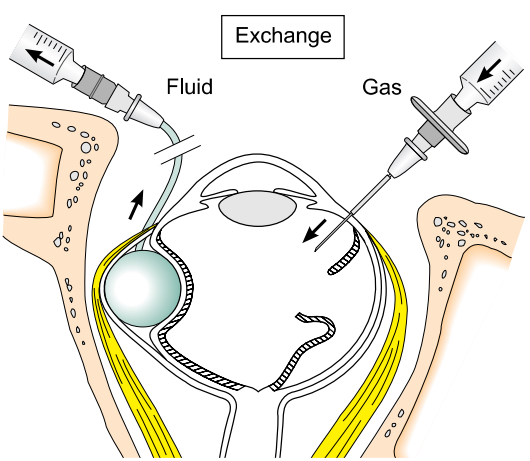


Fig. 10.**32 b** Diagram of *basic balloon–gas procedure:* To treat the giant tear in Figure 10.**32 a** a parabulbar balloon is placed at 9 o'clock to induce internal drainage. After about 2 hours under topical anesthesia by performing a kind of "fluid–gas exchange," 0.7 ml of C_2F_6 is injected without drainage and with preservation of the patient's light perception.

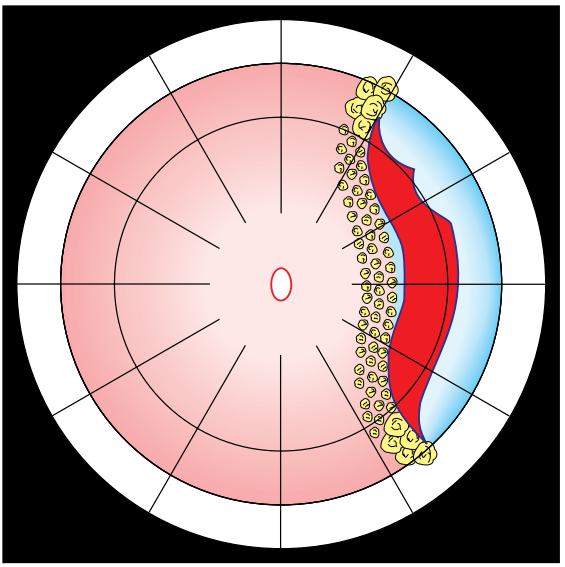


Fig. 10.**32 c** Reattached giant tear 4 weeks after treatment with expanding perfluorocarbon gas without drainage by using the basic balloon–gas procedure. The anterior lateral edges of the giant tear up into the pars plana are treated intraoperatively with cryopexy and the remaining part of the lateral edges and the posterior flap is sealed off with 3 rows of interrupted laser lesions after reattachment. No treatment of anterior flap.

equator, were placed prophylactically to counteract the development of a giant tear on the side opposite to the torn retina (Fig. 10.**32d**).

H. Freeman [44] had reported that a giant tear might develop in every 3rd **fellow eye** during the subsequent years. As a result as prophylaxis we also treated the fellow eye by placing radial laser bars $1^1/_2$ to 2 clock hours apart [45]. During long-term follow-up in about 30% of these treated fellow eyes, tears developed in spite of this prophylaxis. However, these tears were no longer giant tears, but, instead, small horseshoe tears limited in extent. Consequently, their treatment could consist either of laser coagulation alone or of a balloon or sponge buckle.

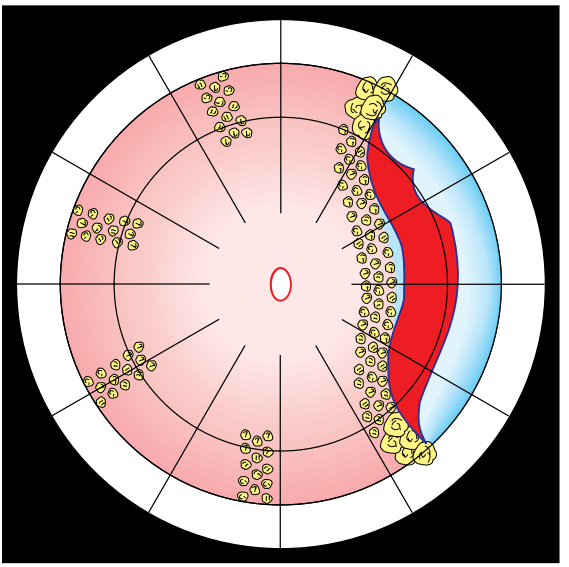


Fig. 10.**32 d** Reattached giant tear after 8 weeks: In 2 sessions 4 radial laser bars are added as prophylaxis against a possible subsequent development of another giant tear.

? What was actually the advantage of radial laser bars as prophylaxis in the fellow eye when small horseshoe tears developed anyway?

▶ **As a result of this prophylaxis the development of a giant tear was avoided.**

10.6.1.2.2 Lateral Giant Tear with Additional Horseshoe Tears

This detachment represents another degree of difficulty.

? Why?

▶ A giant tear is present with additional horseshoe tears (Fig. 10.**33a**).

The attached tear at 7 o'clock was lasered prior to surgery and, in addition, the superior border of the detachment was marked by laser lesions extending from the equator to the pars plana, since it almost coincided with the superior lateral edge of the giant tear.

? Why were these radial laser lesions applied?

▶ To facilitate detection of the upper border of the giant tear when reattached under the gas bubble, which can be most difficult.

Having these laser marks as landmarks you can position the gas bubble more precisely for a sufficient tamponade.

Let us return to surgery. This giant tear detachment was **treated with the extended balloon–gas procedure:**

1. To obtain a larger intraocular gas tamponade.
2. To use the simultaneous buckling effect of the balloon as a tamponade ab externo (Fig. 10.**33b**).

? Consequently, where would you place the parabulbar balloon in this detachment?

▶ It is best to position it beneath the 2 detached horseshoe tears, i.e., to use the balloon buckle in addition as a tamponade for these tears.

Fig. 10.**33 a** Detachment with a lateral giant tear (from 1:00 to 4:30) with 3 additional horseshoe tears. The attached tear at 7 o'clock is surrounded with laser lesions prior to surgery. In addition, the superior border of the detachment is marked with laser lesions into pars plana (since almost coinciding with the superior lateral edge of giant tear) to facilitate the subsequent detection of the superior lateral edge under the gas bubble after reattachment of the giant tear. ▷

b Diagram of *extended balloon–gas procedure*. It is used: 1. To obtain enough space for a larger bubble of CF_4 (expansion potential of 1.9) to tamponade the giant tear (depicted in Figure 10.**33 a**). 2. To buckle at the same time the detached horseshoe tears at 5 o'clock and 5:45. After transconjunctival cryopexy the parabulbar balloon is positioned beneath these 2 tears and filled in steps to a total volume of 1.8 ml. By a kind of "fluid–gas exchange" 0.9 ml of CF_4 is injected into the vitreous with preservation of the patient's light perception. The needle is inserted via pars plana at 11 o'clock, i.e., in an area of attached retina.

Fig. 10.**33 a**

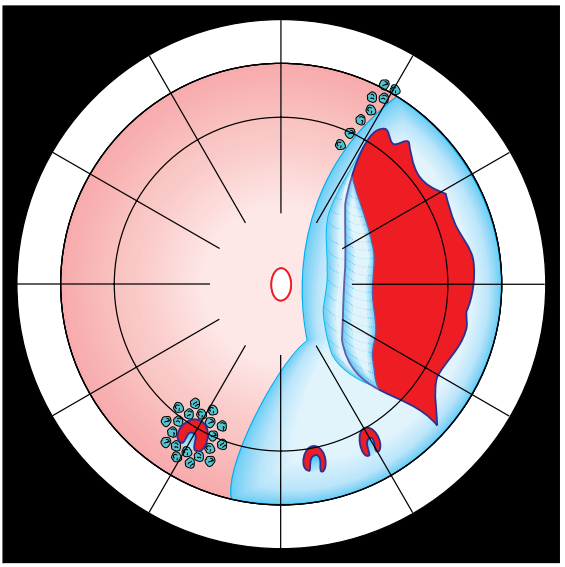
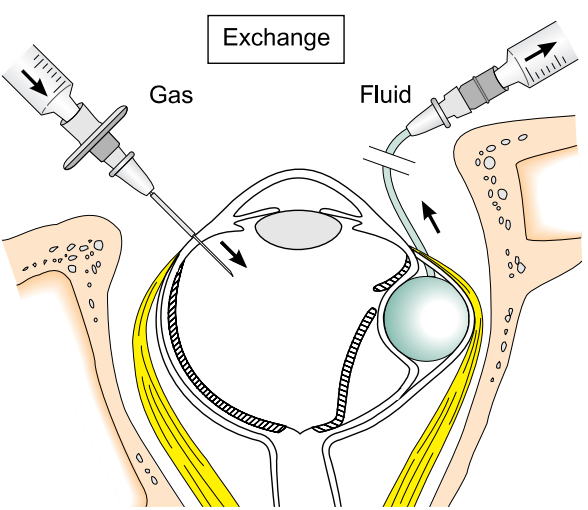


Fig. 10.**33 b**



? What is the advantage of the extended balloon–gas procedure?

▶ – The subsequent gas bubble can be smaller, since the 2 detached horseshoe tears no longer have to be included in the gas tamponade.
– Postoperatively, the indentation of the balloon will define for you the inferior edge of the giant tear behind the gas bubble (facilitating correct positioning of the gas tamponade).
– If at any time the gas bubble appears to be too small, its tamponading effect can be indirectly increased by enlarging the balloon indentation, or the parabulbar balloon can be used for another gas injection (as part of the balloon–gas procedure).

Prior to inserting the balloon, the 2 detached horseshoe tears were surrounded with transconjunctival cryopexy and some additional lesions were placed at the anterior lateral edges of the giant tear up into the pars plana. No cryopexy was applied at the rolled-over flap. The balloon was filled in steps to a total volume of 1.8 ml. After about 2 hours under topical anesthesia the gas was slowly injected in the manner of a fluid–gas exchange. Each time when the patient reported a loss of light perception, fluid was withdrawn from the balloon catheter until 0.9 ml of CF_4 had been injected. The balloon volume was then reduced to about 0.4 ml and the balloon left in place.

The patient was returned to the ward and 6 hours later the balloon was further filled to a volume of 1.0 ml (while monitoring light perception) to provide a sufficient tamponade for the 2 inferior horseshoe tears. Intraocular pressure was checked after 2, 4, and 6 hours. The pressure was initially 28 mmHg, then 20 mmHg. Patency of the central artery was monitored by testing the eye for light perception every 2 hours until the next morning.

? Now how would you position this patient after the gas operation?

▶ The patient was positioned so that the giant tear was in inferior position for the rest of the day with the face down overnight.

? Why?

▶ To wait for the gas bubble to expand, since initially the bubble is still too small to tamponade the entire giant tear.

The next morning, under ophthalmoscopic control, the patient's head was rotated to the opposite side with the nose towards the mattress; the gas bubble moved over the disk towards the posterior edge of the giant tear. The retina was reattached without folds. The reattached edges of the tear were then sealed with 3 rows of interrupted laser lesions in 2 sessions. On the 9th day the gas bubble was too small to provide sufficient tamponade for all of the laser lesions.

? What should you do now?
Re-inject gas into the vitreous?

▶ **No, there is a better and less morbid solution than this. Think for a moment:**
- The balloon volume was enlarged with an additional 0.4 ml of sterile water, injected via the adapter, fixed at the patient's forehead.
- Subsequently the balloon buckle also tamponaded parts of the cryopexied inferior edge of the giant tear and, as a result, the gas bubble could be positioned more superiorly. Now all of the laser lesions were again tamponaded by the gas bubble (Fig. 10.**33c**).
- **No reoperation was needed.**

In the subsequent weeks 3 radial laser bars were added between 8 and 12 o'clock as prophylaxis against future development of another giant tear on the opposite side (Fig. 10.**33d**).

? Which areas of an eye with a gas bubble are especially prone to develop tears?

▶ **The retina opposite the gas bubble,** because the bubble might have exerted traction on the vitreous base.

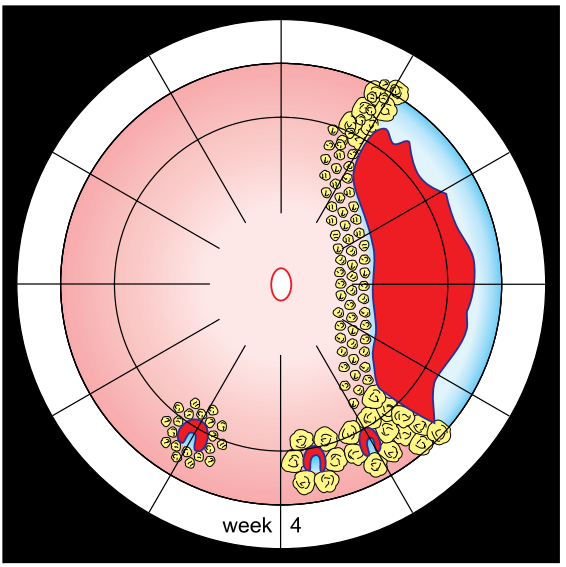


Fig. 10.**33 c** Reattached giant tear and horseshoe tears 4 weeks after an intraocular gas tamponade, cryopexy and laser coagulation: The thermal lesions are pigmented.

? In general, when you examine a patient postoperatively with a gas bubble in the eye, in which part of the retina do you have to search for new tears?

▶ In the retina, of course, which is not tamponaded by the bubble:
Here you may find an attached break or detect an early retinal detachment.

The threat of a gas bubble sliding under the flap of a repositioned giant tear is averted during the first days if the positioning of the patient's head is explained in detail to the patient and to the nurses and how to sustain or re-obtain the correct position of the head (e.g., after going to the toilet). The patient with a giant tear and intraocular gas does not have to maintain this position when washing in the morning, during laser treatment and fundus examination, whilst eating, and whilst going to the toilet.

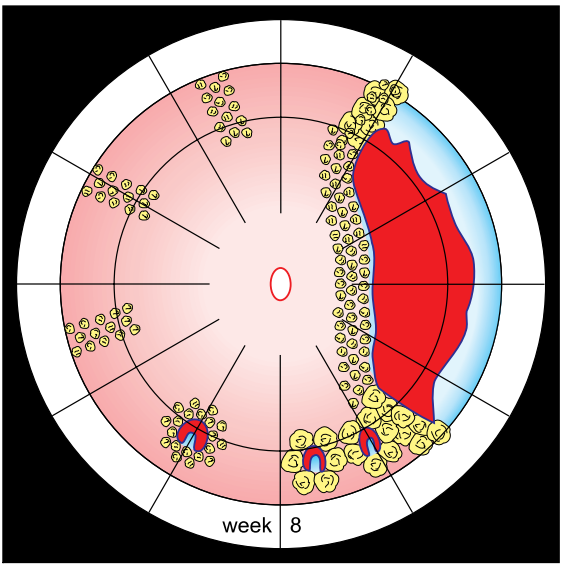


Fig. 10.**33 d** Reattached giant tear and horseshoe tears after 8 weeks: 3 radial laser bars with interrupted lesions are added as prophylaxis to prevent the development of another giant tear in the retina opposite the existing one.

Howewer, as published in 1990 [28], we had become more relaxed about a rigid positioning of the patient's head. The reason was that over the years we experienced that more complications seemed to develop at the vitreoretinal interface in patients which had been very rigid in their head positioning than in patients who appeared as "trouble makers" in this respect.

? As a result, we changed our regimen with an intraocular gas bubble to a treatment with a "Rolling gas bubble": What does this imply?

▶ Here is how to do it.

10.6.1.2.3 Rolling Gas Bubble Technique [28]

After the 2nd or 3rd day, when the giant tear is covered by the gas bubble and the retina is reattached, the patient no longer has to sustain the previous rigid tamponade position, i.e., several times during the day a change in head position is allowed. For the patient this implies an extreme relief of back pain and other discomforts, which might have developed.

? What is the rationale behind the *Rolling gas bubble technique?*

- With this technique we intended to counteract permanent compression of vitreous structures onto the retinal surface, which in our opinion increases the incidence of postoperative PVR [38, 43].
- This more relaxed positioning led to:
  - The postoperative strength of the retinal adhesion not being jeopardized.
  - Vitreoretinal complications seemed to be less.

Now let us resume and look at things in retrospective. So far you did well in treating a giant tear of medium size with an expanding gas bubble. Admittedly its flap was not rolled over very much. Consequently, let us proceed to a more complicated giant tear. But before we do so, here are some questions you might like to ask:

? When reattaching a giant tear, do you rotate the gas bubble during your maneuver or do you rotate the patient's retina?

- With any rotation that you will perform with the patient's head you will always rotate the tear and the retina around the gas bubble.
- **The gas bubble always remains in a superior position.** You should keep this in mind when you use a gas bubble as tamponade and especially when starting with a rotation maneuver.

? When you have injected the gas with the patient lying on the back, where is the gas bubble located at that moment?

▶ It has ascended to the back of the lens and you must rotate the eye and patient around this bubble.

With a lateral large tear, you must first—because of the small size of the not yet expanded gas bubble—rotate the patient so that the tear is in inferior position and the gas bubble is opposite the tear, i.e., uppermost.

● **You must always keep a non-expanded gas bubble away from a large tear.**

Rotating the patient directly after the gas injection, i.e., with a too small, non-expanded gas bubble and the giant tear uppermost, would result in a disastrous complication.

? Which complication?

▶ The small gas bubble might go under the retina through the tear:
"Gas under the retina" represents significant problems!

Consequently, keep in mind the following:

● **After injection of an expanding gas bubble:**
- Always rotate the patient so that the tear (a large or giant tear) is in an inferior position.
- Then the gas bubble will be opposite the tear

Overnight the bubble will expand and press the edges of the detached retina flat. This occurs slowly by driving the subretinal fluid out through the tear and into the vitreous. The patient can only be rotated to the position of maximal gas tamponade, i.e., with the bubble over the tear, after the expanding bubble has flattened the entire retina in-

cluding the edges of the tear. This means that in the presence of a lateral tear the patient will lie on the side opposite the tear.

10.6.1.2.4 Superior Giant Tear with a Flap Overhanging the Disk

As you will see, you can reposition an overhanging posterior flap of a giant tear with a gas bubble. However, presently we might or even would consider repairing such a giant tear (Fig. 10.**34a**) with vitrectomy and a liquid perfluorocarbon to unfold the flap, after which laser is applied to the reattached edges and a fluid–gas exchange performed. If, however, you do not have this technology available or if you are not experienced with vitrectomy, you can use an expanding gas bubble.

To begin with:

▶ **1. How *not* to unfold an overhanging flap of a superior giant tear**

- Do ***not use a large*** gas bubble with backward rotation.

At first we thought that the larger the tear, the larger the gas bubble needs to be to unfold the flap and to cover the tear. This assumption is correct when the flap is not folded over. However, when a giant tear has an overhanging flap and you start with a large gas bubble, you will have an undesirable result.

- ***Clinical example of such a giant tear (Fig. 10.34a)***

This patient was treated in New York when I was working with Prof. Lincoff. After drainage of subretinal fluid a large volume of gas, 2.6 ml, was injected. Our first intention was to unfold the flap with this large gas bubble. The patient was rotated backwards around the gas bubble which remained—as you now know—at the top of the eye during the entire maneuver (Fig. 10.**34b**). However, when the rotation was completed and we looked into the eye with the patient standing up, we found that the flap was not unfolded, but instead compressed in a folded position onto the retina (Fig. 10.**34c**). To correct this, the gas was withdrawn except for 1 ml.

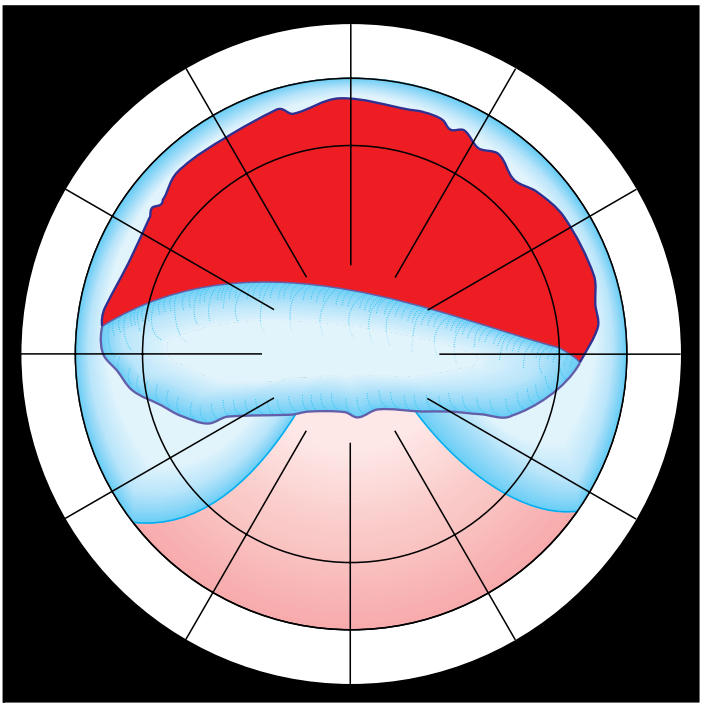


Fig. 10.**34 a** Detachment with a superior giant tear with a flap overhanging the disk.

▶ 2. How *to* unfold an overhanging flap of a superior giant tear

- ***Use a small*** gas bubble with backward rotation.

To begin, let me explain the so-called small gas bubble technique, which was published in 1982 [46].

10.6.1.2.5 Small Gas Bubble Technique

This technique is applied to unfold an overhanging flap of a giant tear. First, let me reassure you that you should not be intimidated by such an overhanging flap when you see it (Fig. 10.**34a**).

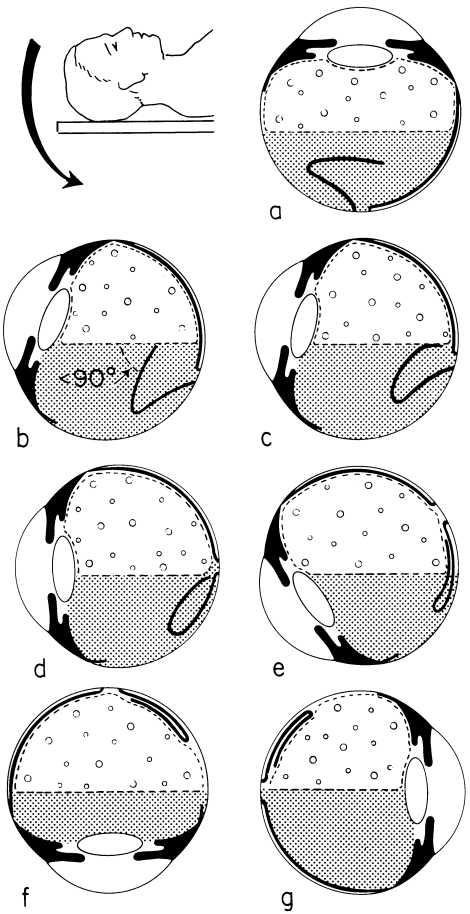


Fig. 10.**34 b** Sequential drawings to demonstrate the effect of rotating an overhanging retinal flap (the patient was rotated backwards) against *a large gas bubble of 2.6 ml*.
The meniscus of the gas bubble makes contact with the flap at an angle of **< 90°**, the flap is compressed towards the retina. **No unfolding of the flap resulted [46].**

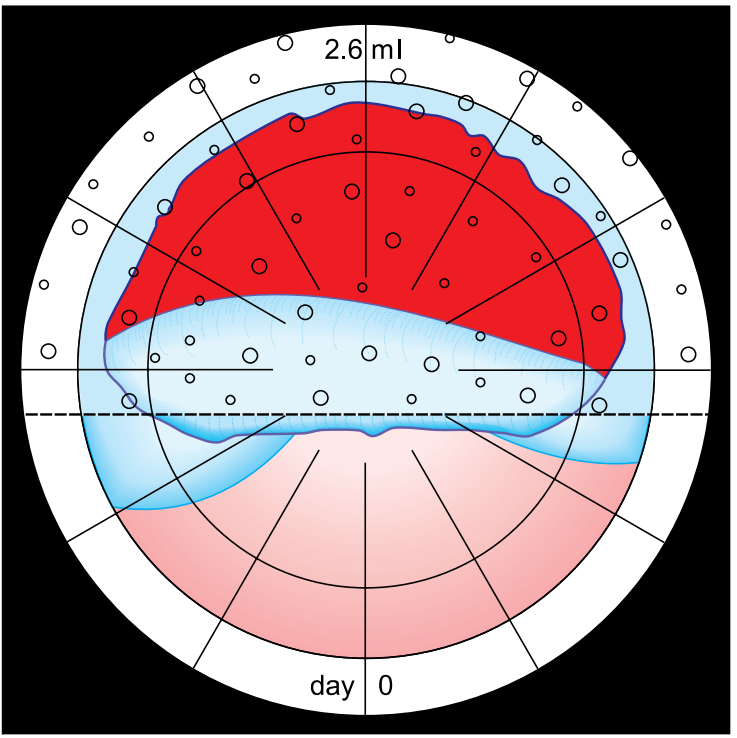


Fig. 10.**34 c** Detachment of Fig. 10.**34 a** after a rotation maneuver with a *large gas bubble* of 2.6 ml. **The flap is not unfolded**, but compressed to the retina.

? Why?

▶ Because there is no traction on the posterior edge of such a flap. The traction is on the anterior flap, otherwise the tear would not have occurred.

Actually it is the anterior flap that is standing up, because it is being pulled upon by the vitreous, whereas the posterior flap is hanging loose and will go back easily with the slightest push. This can be done with a small gas bubble that will approach the flap from the

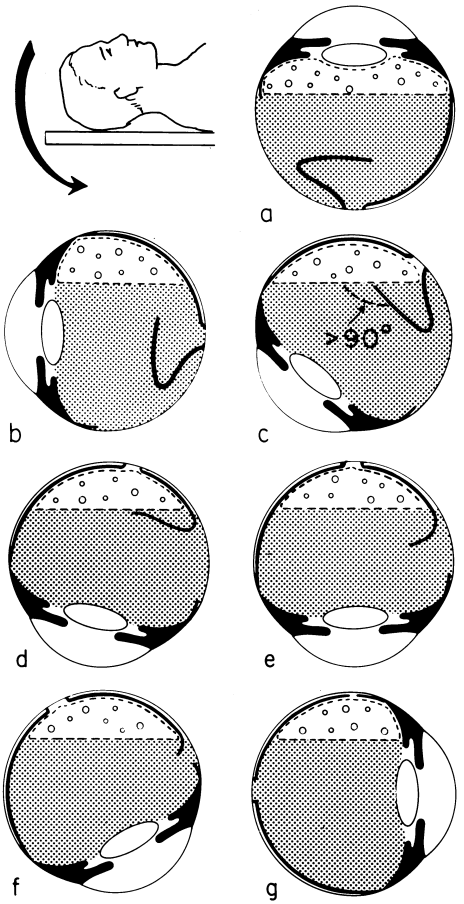


Fig. 10.**34 d** Sequential drawings to demonstrate the effect of rotating an overhanging retinal flap against *a small gas bubble of 1 ml*.
The meniscus of the gas bubble makes contact with the flap at an angle of **> 90°** and thus **the flap was unfolded.**

disk and slide under the flap to unfold it. We recall that a gas bubble of 1 ml has a maximal thickness of 6 mm in the center [47]. When the flap of the giant tear is rotated against such a small gas bubble, the bubble will slide like a thin wafer under the flap.

? Here is an answer to a question you might have already posed earlier: How should you proceed when backward rotation is needed?

▶ Here is how it is done.

10.6.1.2.6 Backward Rotation around a Small Gas Bubble

This can be performed either by positioning the patient on an orthopedic stretcher or as a simple alternative, as we had practiced, over a padded bar. In this respect it is fortunate that giant tears occur in younger patients.

? But how should you proceed during surgery when, in the absence of a rotating table, a backward rotation is needed?

▶ Slide the patient's head beyond the edge of the operating table, then rotate the patient's lower torso with assistance slowly across the padded bar for 270° to a standing position.

With the smaller 1 ml gas bubble of C_2F_6 the backward rotation maneuver was repeated in the previous patient and the retina observed by ophthalmoscopy (Fig. 10.**34d**).

● Indeed, when the edge of the overhanging flap approached the gas bubble,
the small bubble slid beneath the flap and unfolded it.

But the bubble was too small to tamponade the entire tear (Fig. 10.**34e**). Consequently, until the gas bubble expanded to 3.4 ml in 3 days, the patient was positioned prone with the head elevated

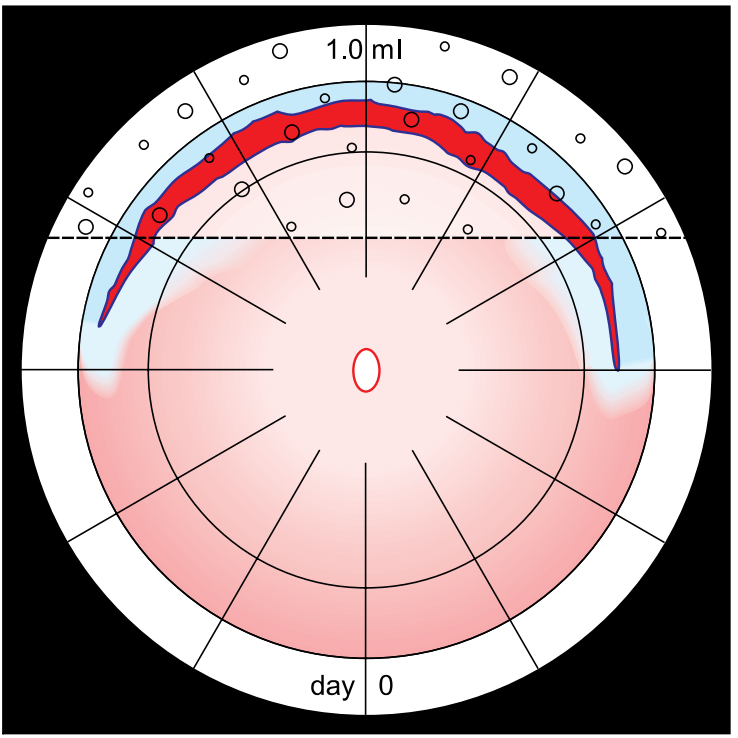


Fig. 10.**34 e** The flap of the giant tear was unfolded by the *small gas bubble* of 1.0 ml, which, however, is too small for a full tamponade of the tear. The gas volume will increase after expansion.

30°. On the 3rd day the retina was reattached and the bubble covered the entire tear (Fig. 10.**34f**). Subsequently the edges of the tear were treated with transconjunctival cryopexy (Fig. 10.**34g**); they could have also been secured with laser lesions.

The patient no longer had to sustain a prone position, but could walk around with the head in an upright position. During sleep the head had to be elevated 30°. After 24 days the gas bubble had decreased to 0.8 ml and the cryopexy lesions had become pigmented (Fig. 10.**34h**).

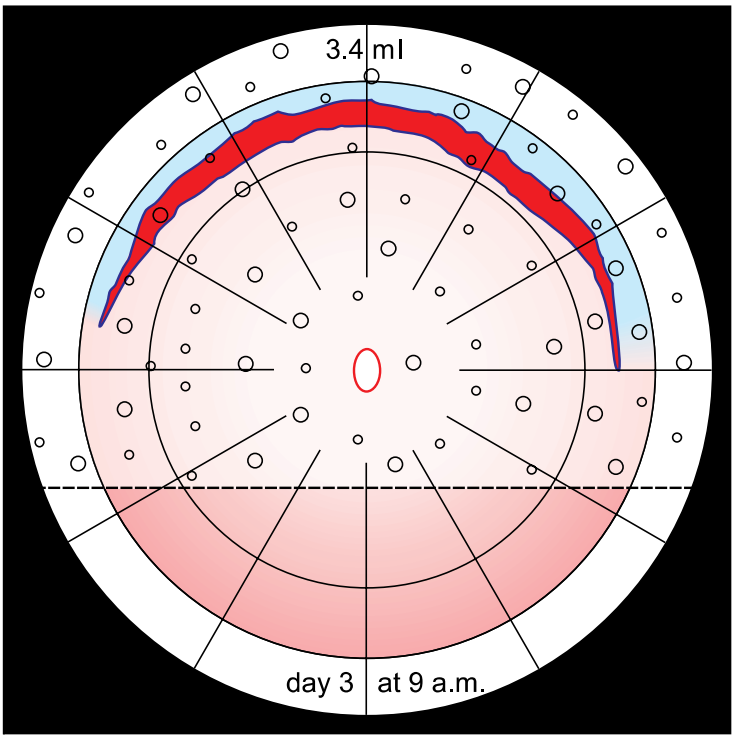


Fig. 10.**34 f** On the morning of day 3: The gas bubble has expanded to a maximal volume of 3.4 ml, the entire tear is tamponaded by the bubble.

During the entire period the gas bubble was in the eye, no cataract developed (due to optimal positioning keeping $^2/_3$ of the lens free of gas). In the subsequent weeks one might consider—as we did—adding radial laser bars, $1^1/_2$ clock hours apart, as prophylaxis to counteract the development of a giant tear in the opposite retina.

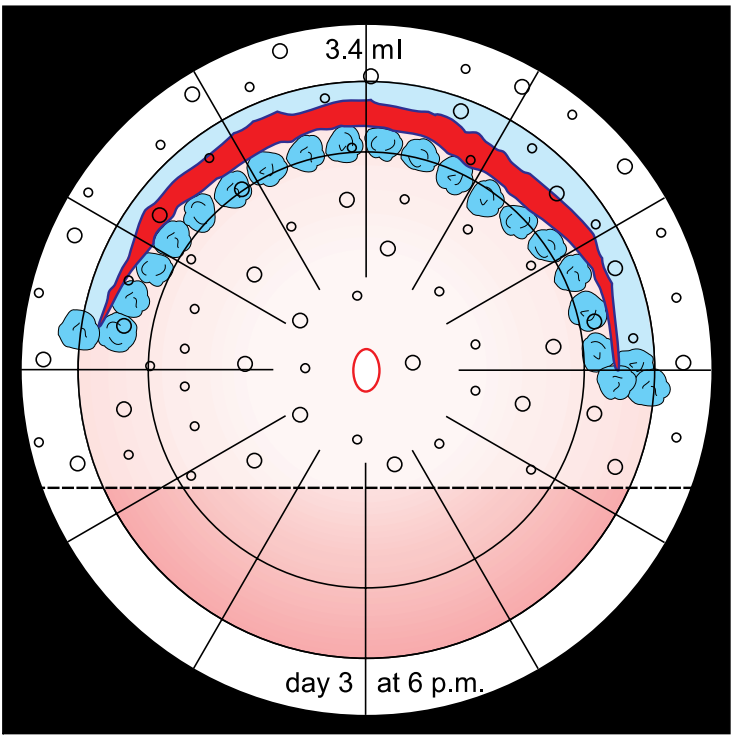


Fig. 10.**34 g** In the afternoon of day 3: Transconjunctival cryopexy lesions are added to secure the posterior and lateral edges up into the pars plana of the reattached tear. The anterior flap is not treated.

- The treatment of this difficult giant tear detachment could have consisted primarily of a gas injection of **0.8 to 1 ml of C_2F_6 by using the basic balloon–gas procedure,** followed by a backward rotation to unfold the flap, prone positioning for 3 days with the head elevated 30°, and subsequent cryopexy or laser treatment of the reattached edges of the tear.

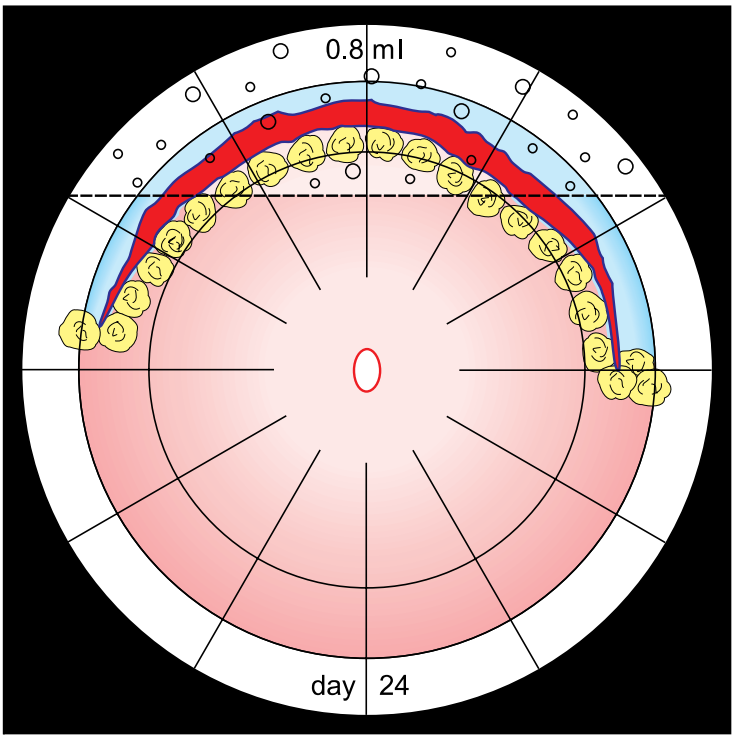


Fig. 10.**34 h** At day 24: The reattached and unfolded giant tear is secured with pigmented cryopexy lesions. Special care was taken to seal off the lateral edges of the tear into the pars plana, but the anterior flap was not treated. During the next 8 weeks several prophylactic radial laser bars ($1^1/_2$ clock hours apart) were applied to the retina opposite the reattached giant tear.

- With this regimen a prior drainage was not needed and the entire treatment consisted of:
  Small procedures performed under local anesthesia.
  Neither was a vitrectomy needed.

10.6.1.2.7 Superior Giant Tear with a Flap Overhanging the Disk and Additional Horseshoe Tears

Figure 10.**35a** represents another example of a superior giant tear sent for treatment. However, this time it is your turn to work out the treatment steps.

? Which findings of the detachment represent an additional problem?

▶ The 2 additional horseshoe tears which are slightly detached.

? But what is favorable about these 2 tears?

▶ They are only slightly detached and are in an inferior location.

? What should be done?

▶ To begin with, laser the posterior edges of the 2 tears and the adjoining lattice degeneration which are practically attached. Afterwards double patch and lie the patient flat for 1 day.

The next morning the superior detachment and the overhanging flap did not change, however, the inferior tears were almost attached. Now you have to plan the surgery.

? What should be done and in which succession?

▶ To be able to inject without prior drainage 1 ml of an expanding gas (needed to unfold the overhanging flap with the small gas bubble technique), you will have to apply the extended balloon–gas procedure.

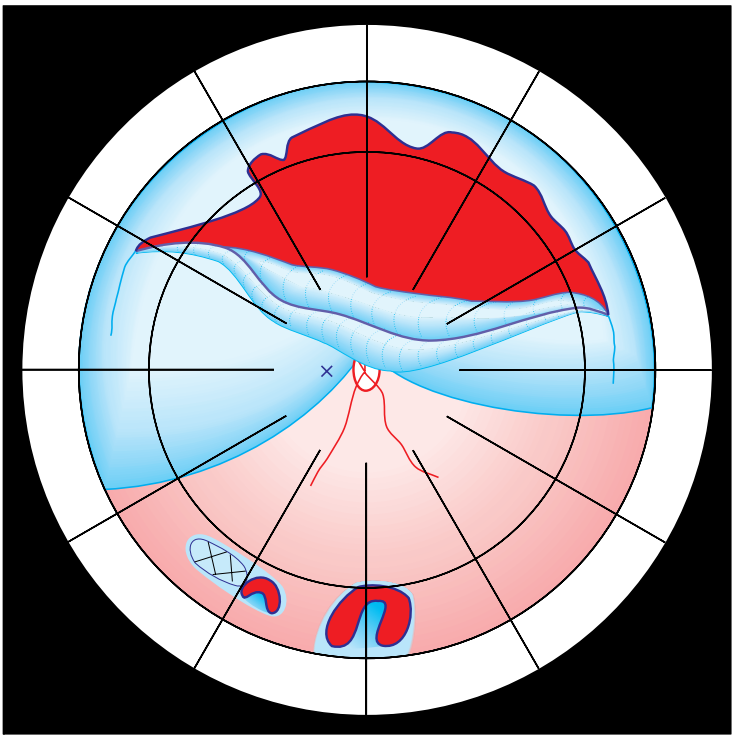


Fig. 10.**35 a** Superior giant tear with a flap overhanging the disk and horseshoe tears in a 39-year-old patient. Visual acuity 20/200.

? Where should you place the parabulbar balloon?

▶ Beneath the slightly more detached and larger horseshoe tear at 6 o'clock.

? But what do you have to do first?

- Perform transconjunctival cryopexy for the **Following 2 reasons:**
  - **To induce retinal adhesions.** To begin with you will complete the inferior coagulations around the 2 tears and the lattice degeneration. Thereafter you will apply cryopexy at the lateral edges of the giant tear at 10 o'clock and 2:30, and as prophylaxis against further tearing in an inferior direction you will add cryopexy lesions on either side of the giant tear for another clock hour into the area of the visible traction line. Then additional cryopexy lesions will be placed up into the pars plana.
  - **To induce ocular decompression with the cryoprobe.**
- A parabulbar balloon is afterwards positioned beneath the slightly detached horseshoe tear at 6 o'clock, and by applying the balloon–gas procedure almost 1 ml of C_2F_6 is injected without drainage (check central artery for pulsation!).
- By using the small gas bubble technique with backward rotation of the patient, the posterior flap of the giant tear is unfolded.
- The subsequent patient positioning and treatment follows the regimen already described in Figures 10.**34c, d, e,** and **f**.

After the gas bubble has expanded and tamponaded the entire giant tear, cryopexy lesions are applied at the reattached posterior edge. In Figure 10.**35b** the retinal findings are presented 4 weeks after treatment. Some laser lesions were added to secure the posterior edge of the giant tear. The inferior tears are sufficiently surrounded by pigmented scars. Visual acuity of this 39-year-old patient was 20/200 prior to surgery and improved to 20/25 at 6 months after surgery. In the subsequent weeks a prophylactic radial laser bar was added at 4:30. During the entire follow-up of 6 years, no redetachment developed and visual acuity remained unchanged.

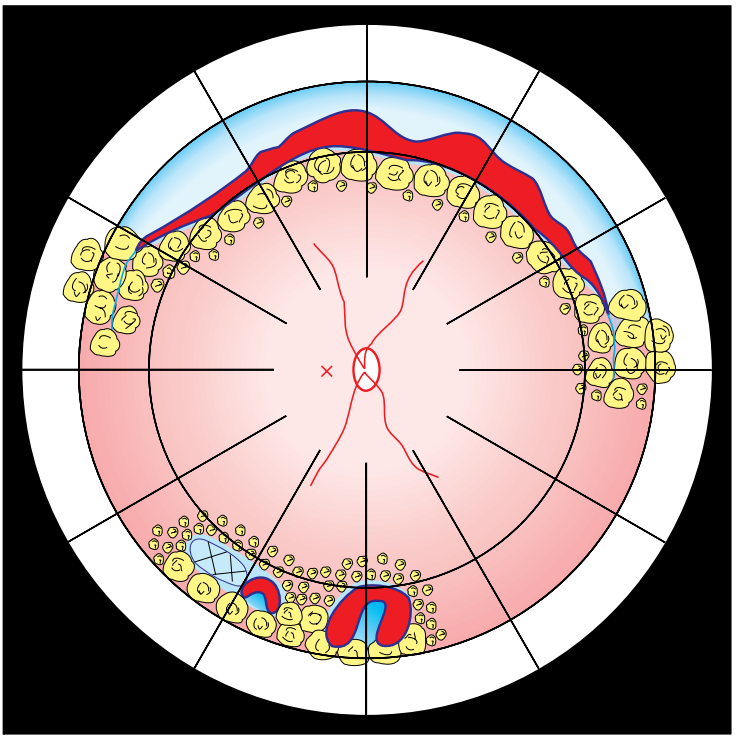


Fig. 10.**35 b** As the 1st step of treatment the posterior edge of the 2 inferior tears and the adjoining lattice degeneration, practically attached, were treated with laser lesions. By applying the *extended* balloon-gas procedure (the parabulbar balloon was positioned beneath the horseshoe tear at 6 o'clock), almost 1 ml of C_2F_6 without drainage was injected and the overhanging flap unfolded by using the small gas bubble technique with backward rotation. Cryopexy was applied, to seal off completely the inferior tears and lattice degeneration and to the posterior and lateral edges of the giant tear. As prophylaxis (to counteract future tearing) cryopexy lesions were extended into the pars plana and inferiorly on either side of the lateral edges of the giant tear into the area of a visible traction line. Subsequent laser coagulation was added as needed. Visual acuity had improved to 20/25 at 6 months.

10.6.1.2.8 Superior Lateral Giant Tear with Detached Horseshoe Tears and Moderate Vitreous Hemorrhage

This detachment occurred in a young patient. The macula was still attached, the lens clear, and the visual acuity was 20/20. There were multiple tears at various latitude and a small inferior hemorrhage in an emmetropic eye (Fig. 10.**36a**). This patient was treated by Prof. Lincoff in New York during the time that I was working there. The fellow eye had no retinal pathology.

? What should one do in the situation of such a difficult detachment?

▶ **The patient still has full visual acuity:**
The problem is how to reattach the retina and not to jeopardize the full visual acuity by complications in the short- or long-term.

● **Here are 3 alternative treatments which should be evaluated:**

1. **A primary vitrectomy with heavy perfluorocarbon liquids and an intraocular gas bubble.**
   Be aware that in the long run you have to sacrifice the clear lens of this young patient and that other secondary complications (PVR, new breaks) can be expected.
2. **An expanding–gas operation without vitrectomy.**
   You will need a very large gas bubble, i.e., you will have to use an expanding gas with a large expansion coefficient and, as a result, with a long intraocular duration, all of this in the presence of a vitreous already irritated by the intraocular hemorrhage.
3. **An expanding–gas operation without vitrectomy** (as treatment for the superior tears) combined **with a segmental buckle** (as treatment for the inferior tear).

? What are the advantages of option 3?

▶
- A smaller gas bubble will be needed, since the inferior tear is buckled.
- As result, a gas of less expansion and therefore of shorter intraocular duration can be selected.

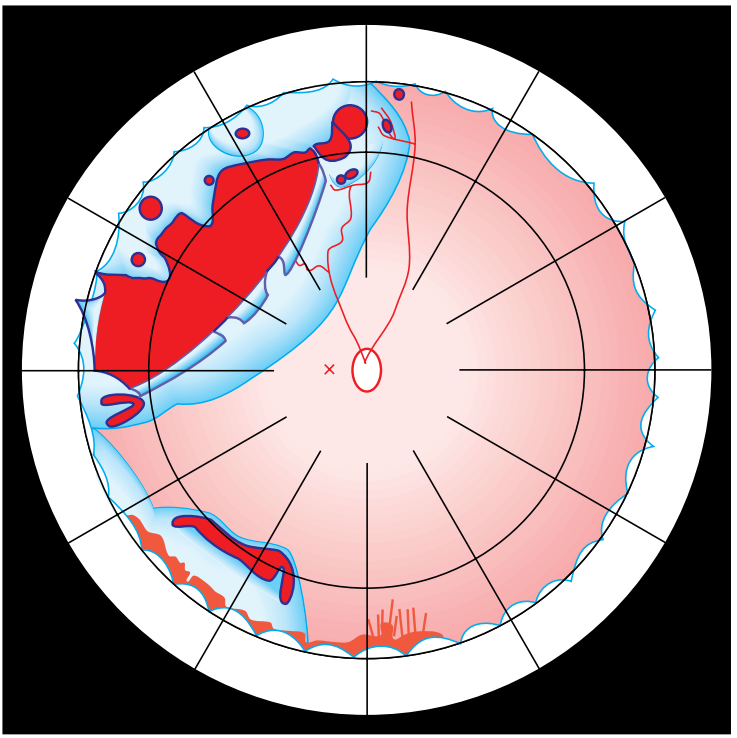


Fig. 10.**36 a** Detachment with a superior lateral giant tear with irregular edges, detached horseshoe tears and moderate vitreous hemorrhage in a young patient: The macula was still attached. In addition, there were multiple detached tears at different latitude with a small inferior hemorrhage. To detect all of these intraoperatively, the neighboring vessels were documented.

- The above will reduce the risk of subsequent complications.
- As a result, the operation will less jeopardize long-term visual acuity.

Now we will demonstrate what was actually done with this patient. To begin with, the large horseshoe tear at 7 o'clock, not detached posteriorly (and therefore not harboring the threat of posterior leakage by radial folds), was placed on a short circumferential buckle after being surrounded with cryopexy lesions.

? Why not instead use a balloon to tamponade this inferior tear?

- The horseshoe tear was too large to be buckled sufficiently by a balloon.
- In addition, a permanent buckle was preferred, because it was to be expected that the blood in the close vicinity of the tear would increase traction on the operculum.

After the horseshoe tear was buckled, the additional tears and the giant tear were treated with cryopexy, but again not the anterior flap of the giant tear. Since the eye had become hypotonic after the indentations with the cryoprobe,

A parabulbar balloon was inserted at 2 o'clock:

1. To compensate for the decreasing intraocular pressure.
2. To be used subsequently as part of the basic balloon–gas procedure.

The eye was patched and the patient's head tilted to the right and positioned flat to place the giant tear in an inferior position. During the next hour the patient was kept in the operating area and the balloon volume was increased in steps to 1.5 ml. Subsequently, 0.8 ml of C_2F_6 was injected into the vitreous by applying the balloon–gas procedure.

? 0.2 ml of fluid was left in the balloon: Again, why?

To be withdrawn on the ward in case of an abrupt increase of intraocular pressure during the subsequent hours.

After surgery the patient remained flat on the right side to keep the gas bubble away from the giant tear. Since intraocular pressure did not increase, the balloon was withdrawn the next morning. When the gas bubble had expanded to 2.6 ml, the patient was rotated—as already described—in a face-down position over the stomach to the other side, the final tamponade position. The head was now on the left

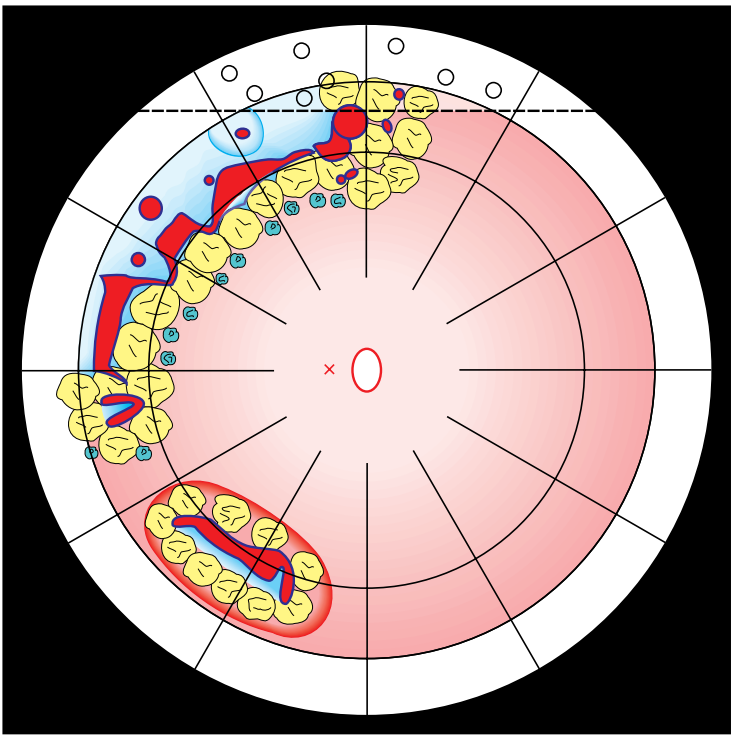


Fig. 10.**36 b** The treatment was divided into **2 steps: 1.** The horseshoe tear between 6:30 and 8 o'clock was supported by a short circumferential buckle without drainage. **2.** The superior tears were treated with cryopexy lesions, but not the anterior edge of the giant tear. Prior to injection of gas, a parabulbar balloon was inserted at 2 o'clock, and by using the *basic* balloon–gas procedure 0.8 ml of C_2F_6 was injected without drainage. After expansion of the gas bubble and adequate positioning of the patient's head all of the tears had reattached. In some areas laser lesions were added. Subsequently all of the lesions were pigmented, the tears secured and the retina reattached. However, as long as some gas was in the eye, the patient had still to sleep with the head elevated for 30° on either side.

side and elevated about 30°. In this position the giant tear and the unbuckled tears were sufficiently tamponaded by the gas bubble. After some days additional laser lesions were added (Fig. 10.**36b**).

During the follow-up of 5 years no redetachment occurred. The visual acuity of 20/20 had not decreased during that period of time and the segmental buckle did not interfere with ocular motility. No secondary cataract or glaucoma developed.

10.6.1.2.9 Superior Giant Tear Posterior to Equator with Rolled-Over Posterior Flap and Detached Horseshoe Tears

This detachment represents another degree of difficulty (Fig. 10.**37a**).

? What does this mean?

- The giant tear has an extent of more than 135°.
- There are additional large horseshoe tears which are detached.
- The giant tear, besides having irregularly torn edges, is located more posteriorly.
- The posterior flap is rolled over.
- **In spite of these difficult retinal findings the macula is still attached and the patient has a visual acuity of 20/25.**

? What should be done?

- A primary vitrectomy with heavy perfluorocarbon liquids and an intraocular gas tamponade, a method everybody would think of today?
- **What else?**

Yet when this patient was sent to us, the heavy perfluorocarbon liquids were not yet available, vitrectomy had just appeared on the horizon, and its indications for these findings were still pending. In addition this was the only eye of the patient with a clear lens. The sight of the fellow eye was lost due to a giant tear operated upon 3 years earlier.

- **Whatever would be done to this eye, visual acuity could only be at risk, i.e., decrease.**
- **You should bear in mind this consideration when deciding upon any treatment modality.**

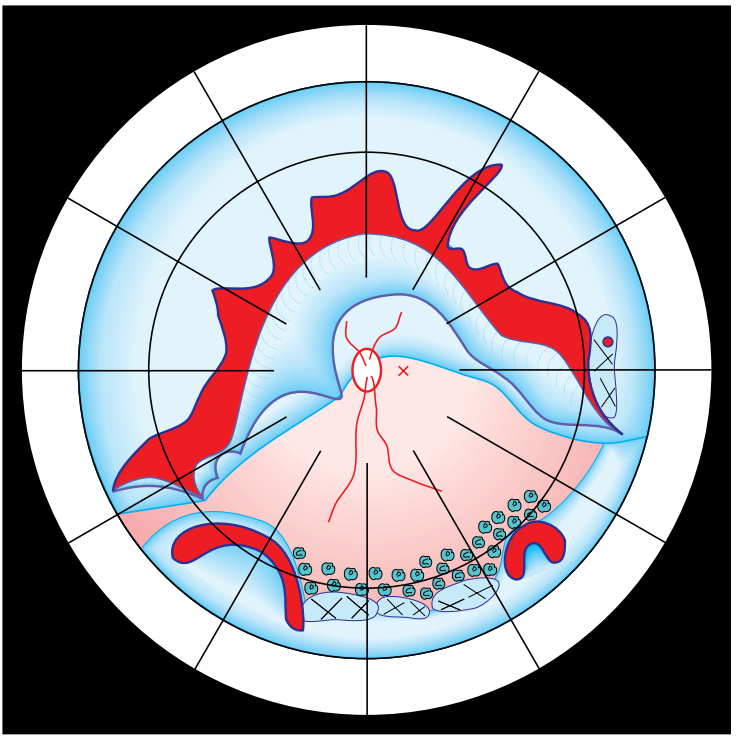


Fig. 10.**37 a** Detachment with a superior giant tear posterior to the equator with irregular edges, rolled-over posterior flap, and detached horseshoe tears. This is the only eye of a patient, visual acuity ranges at 20/25. The treatment was divided into **3 steps: 1.** During the day of double patching laser lesions were applied to the posterior border of the lattice between 5 and 7 o'clock and to the attached posterior edge of the horseshoe tear at 4:30.

- Admittedly, when primarily performing a minimal procedure in such a difficult giant tear detachment, you must have patience and confidence.
- After all, as you may now recall, the only thing that counts for the patient in the long run is sustained retinal reattachment and favorable long-term visual acuity not being jeopardized by early or late complications.

Here is a piece of advice which might be of help:

- **If confronted with a complex detachment and when you do not know right away what to do:**
  - **It is better to wait** for a day and re-think your treatment strategy
  - **Than to do too much too early,** resulting in irreversible complications.

Of course, during this period of planning you have to double patch the eyes and position the patient's head to avoid progression of the detachment. However, during that day of re-studying you should already start with the 1st treatment step.

Here the 3 steps of treatment:

— 1. Laser coagulation to the attached posterior edge of the 1 inferior horseshoe tear and lattice degeneration

After evaluating the options, the treatment of this complex detachment was divided into **2 further steps**:

— 2. An expanding–gas operation with cryopexy

Using the basic balloon–gas procedure, an expanding gas bubble of 0.8 ml of C_3F_8 was injected and the lateral edges of the giant tear cryopexied. To unfold the posterior flap of the giant tear the ***small gas bubble technique*** was applied with a backward rotation of the patient. The small, not yet expanded gas bubble of 0.8 ml was used for this maneuver. After successfully unfolding the flap and after the gas bubble had reached a volume of 3.2 ml, the giant tear was reattached and the last step of surgery was added.

— 3. Segmental buckling and cryopexy

The 2 inferior horseshoe tears were cryopexied and each of them supported by a separate radial buckle. In addition, the reattached posterior flap of the giant tear was treated with cryopexy lesions. Some days later laser lesions were added as needed (Fig. 10.**37b**). Visual acuity was 20/25 after 3 months.

? What did we learn after treating this complex detachment with several small procedures?

- — First of all; not to panic or over-react when confronted with a difficult retinal problem.

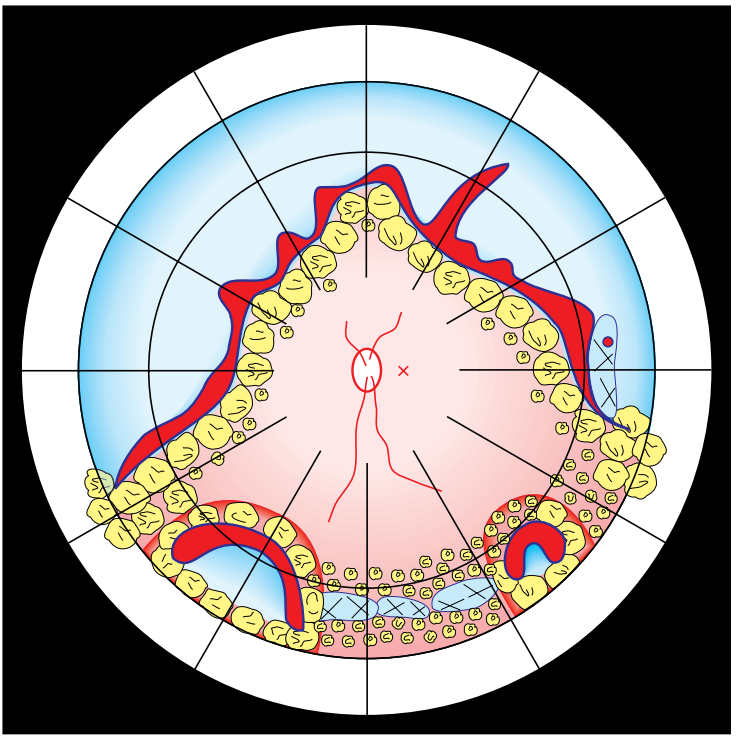


Fig. 10.**37 b** **The treatment was divided into 3 steps: 1.** Laser coagulation to the attached posterior edge of 1 horseshoe tear and lattice degeneration. **2.** An expanding gas bubble of 0.8 ml of C_3F_8 was injected using the *basic* balloon–gas procedure without drainage, and the lateral edges of the giant tear cryopexied. To unfold the posterior flap, the small, i.e., not yet expanded, gas bubble was used with a backward rotation. After expansion of the gas bubble, the giant tear was reattached on the 3rd day. At that moment the patient was returned to the operating room. **3.** The 2 inferior horseshoe tears were surrounded as needed with cryopexy and each supported by a radial sponge. Additional cryopexy was added to the reattached posterior edge of the giant tear, and the lesions were continued into the pars plana (at 8 o'clock and 3:30) to prevent further tearing. Subsequently, laser coagulation was added as needed. Visual acuity ranged at 20/30 after 2 months, at 20/25 after 3 months, and remained unchanged during the next 4 years. – Vitrectomy and heavy perfluorocarbon liquids were not yet available when the patient was sent to us.

- Instead, to try to divide the treatment into several procedures, each of which will be smaller and less morbid.
- If the detachment appears to be too difficult for you to let someone more experienced do it.

? Why at this early stage?

▶ Because as you might recall:
The 1st operation determines the future of the eye, i.e., its prognosis and long-term visual acuity.

10.6.1.2.10 Giant Tear of 350° with an Inferior Rolled-Over Posterior Flap

To begin with, a detachment with an inferior giant tear and a rolled-over flap represents a rare finding. This giant tear of 350° was observed in a young myopic (–8 dpt) patient (Fig. 10.**38a**). There were pigment cells (Tyndall 3+) in the vitreous. Today, with the availability of the heavy perfluorocarbon liquids in combination with vitrectomy, this would represent the treatment of choice.

However, if this modality should not be available to you—as was the situation with us in 1982—then there might be another option, admittedly more laborious, for treating such an extensive giant tear and unfolding an inferior flap. Reflect for a moment.

? First, how would you start your treatment?

▶
- Apply laser lesions to the still attached posterior edge of the tear between 10 and 12 o'clock. Then double patch the patient with the head in flat position for a day. However, the expected result, additional flattening of the posterior edge of the tear, did not occur.
- Divide the intended expanding-gas operation into several steps, because the tamponade you will need has to be very large.

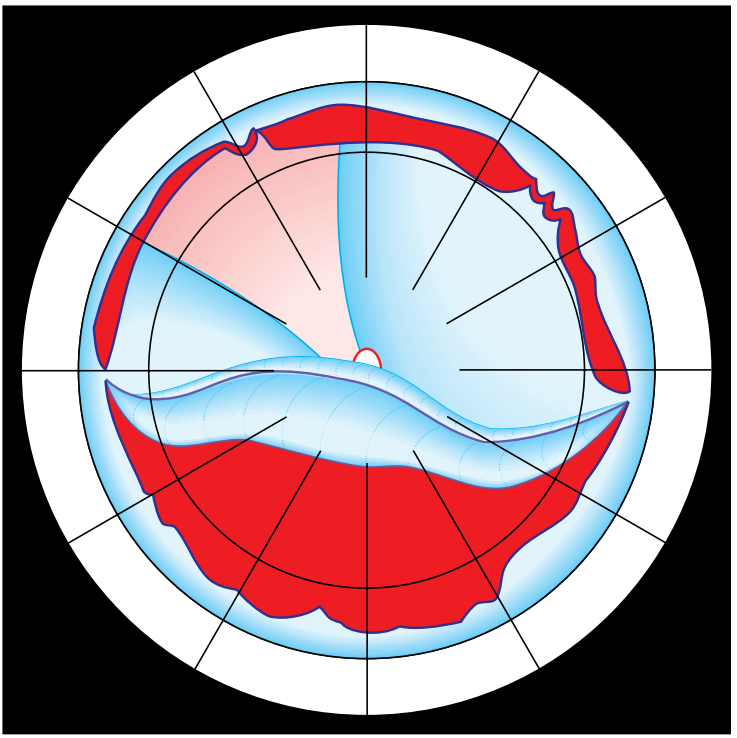


Fig. 10.**38 a** A myopic eye (−8 dpt) with a detachment and a giant tear of 350° in extent with an inferior rolled-over posterior flap, a rare finding: Between 10 o'clock and 11:45 the posterior edge of the tear was still attached. Pigment cells (Tyndall 3+) were in the vitreous. This patient was sent to us in 1982, when vitrectomy with the use of heavy perfluorocarbon liquids was not yet available.

? What, again, would be the first step during the gas operation?

▶ To unfold the inferior posterior flap.

? How would you do this?

▶ Use the small gas bubble technique, but this time **rotate the patient forward.**

10.6.1.2.11 Forward Rotation around a Small Gas Bubble

? How do you proceed?

▶
- Patch the eye, into which you just have injected a small gas bubble, and provide sufficient drapes on the floor in the operating room to sustain asepsis around the patient's head.
- Subsequently, spread a pad on the floor and let the patient turn a slow forward somersault with assistance. It was fortunate that the patient was young.
- Now check the retina to see whether the flap is unfolded.
- This has resulted.

The subsequent treatment consisted of 3 injections of C_3F_8 – the balloon-gas procedure was not yet developed [42] – combined with cryopexy, followed by 2 segmental circumferential buckle operations—6 weeks apart—to tamponade secondarily leaking edges of the giant tear. Sufficient scarring was supplemented by several laser applications (Fig. 10.**38b**).

●
- Altogether the gas tamponade had been in the eye for 10 weeks, but the retina was reattached and visual acuity was 20/50.
- However, it should be pointed out that this extraordinary result, obtained without vitrectomy and without heavy perfluorocarbons, was only feasible by a "tour de force," i.e., by optimal compliance of the patient and extreme motivation and cooperation of the doctors and nurses responsible.

Only in this 1 patient had a postoperative cataract developed. Keep in mind that there was a large gas bubble of 10 weeks duration. Slit

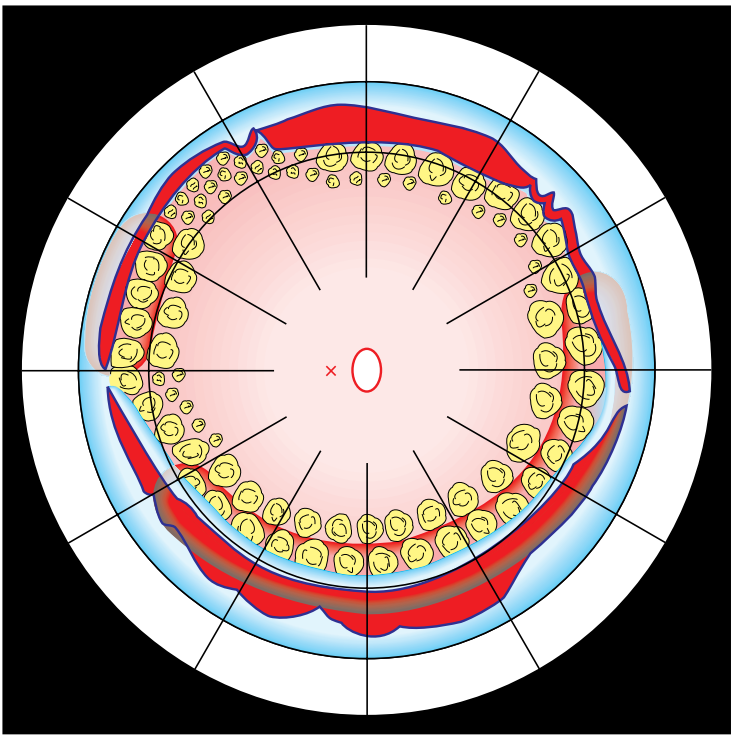


Fig. 10.**38 b** As 1st step of treatment laser lesions were applied to the attached posterior edge of the tear between 10 o'clock and 11:45, followed by double patching with positioning the patient flat for 1 day. No change occurred. Then, using the *small gas bubble technique,* the rolled-over inferior flap was unfolded with a forward rotation. To provide a sufficiently large gas tamponade 3 injections of C_3F_8 were added. When subsequently the reattached posterior edge of the giant tear started to redetach in some areas, reattachment was obtained by 2 segmental circumferential buckle operations, 6 weeks apart. Altogether the gas was in the eye for 10 weeks. Thereafter, the retina was completely reattached and visual acuity ranged at 20/50. Almost 15 years later, a cataract was removed. After that visual acuity ranged at 20/40, i.e., more than $17^3/_4$ years after treatment of this giant tear detachment. No redetachment had occurred during the long-term follow-up.

lamp examination revealed that condensed vitreous had become adherent to the posterior surface of the lens, a result of the long-term intravitreal gas tamponade. Visual acuity had decreased to 20/400 after $2^1/_2$ years; however, with laser inferometry it was in the range of 20/50. During the long-term follow-up the retina remained attached. The mature cataract was removed 15 years later by phakoemulsification. Visual acuity had improved to 20/40 and remained unchanged up to $17^3/_4$ years after detachment surgery.

Following the treatment of the giant tear, several prophylactic radial laser bars were applied to the fellow eye [45]. No giant tear had developed in this eye during the entire long-term follow-up.

After discussing the treatment of large and giant retinal tears, let us move on to the next application of the expanding-gas operation.

10.6.2 Group of Breaks at Different Latitude

A group of breaks within 1 clock hour—independent of whether they are in a superior or inferior location—present an indication for the balloon operation (see Chapter 9.6, pp. 25–91). An alternative treatment, but restricted to a group of breaks in the superior $^2/_3$ of the eye, represents pneumatic retinopexy. However, the greater morbidity of the latter favors the external balloon buckle. The difference between these 2 procedures in treating uncomplicated retinal detachments will be discussed below (see Chapter 11, pp. 271–287).

But so much so far: Pneumatic retinopexy implies treating uncomplicated detachments, but not treating detachments containing tears unsuitable for external buckling. For these more difficult retinal detachments the expanding-gas operation [17, 27, 31] harbors less morbidity than extensive buckling would.

However, a pitfall:
The expanding-gas operation will reattach the retina, but only temporarily, if not all of the breaks have been detected and sufficiently treated.

? Why?

▶ Because a large intraocular **gas bubble** will tamponade and reattach any break beneath it;
however, this will only be **temporary** if it is not secured by thermal lesions.

An intraocular perfluorocarbon gas bubble will expand 2 to 4 fold, enough to cover nearby undetected tears and reattach the retina. As a result, in the presence of a large intraocular gas bubble be aware that reattachment does not necessarily imply that the retinal detachment is cured.

● Reattachment might only be present as long as the gas bubble persists.
- This sequela is comparable to reattachment after drainage of subretinal fluid:
  The moment of truth comes when the gas bubble recedes:
  Since untreated, i. e., not coagulated, tears will redetach.

This sequela represents a problem when applying the expanding-gas operation for multiple tears located at different latitude.

? How can you avoid such a drawback?

▶ In general, a retinal hole is recognized as a red spot within opaque, i.e., detached, retina.
However, when the hole is reattached by the gas bubble, it is more difficult to identify the tear.

? What should be done?

▶
- **Prepare preoperatively** for this situation, i.e., make a precise fundus drawing and document vessels or obvious structures in close proximity to the various holes to be detected intraoperatively or postoperatively behind the gas bubble.
- **Treat intraoperatively** those tears with cryopexy which will be tamponaded by the gas bubble 1 day after surgery.

– Seal off the remaining tears postoperatively after reattachment with laser lesions through the gas bubble.

Some advice:

Examination of the retina or performing laser coagulation through a gas bubble can be done best by using an *indirect contact lens*.

10.6.2.1 Group of Breaks and Posterior Hole

Shown here is a detachment with a group of breaks at different latitude and a posteriorly located hole (Fig. 10.**39a**). The macula is slightly detached, visual acuity is 20/25. The holes are small and round. To identify for certain all of them during surgery, the neighboring vessels were precisely documented.

The superior 3 holes were cryopexied and a parabulbar balloon placed beneath them. The bullous quality of the detachment of the 3 holes presented a difficulty during localization of the balloon. However, the balloon was primarily intended as part of the balloon-gas procedure to enable the injection of a larger bubble of a gas with less expansion potential and thus a shorter intraocular duration (Fig. 10.**39b**). After $1^1/_2$ hours of oculocompression, 0.8 ml of CF_4 was injected into the vitreous. Since, however, the balloon seemed correctly placed under the 3 more anterior holes, 0.3 ml of fluid was left in the catheter to maintain its position postoperatively. The patient's head was elevated 45° and tilted to the left.

The next morning the balloon was filled with an additional 0.8 ml of fluid to provide sufficient tamponade for the anterior group of holes. When the gas bubble had expanded to 1.5 ml, the patient was positioned flat and the head turned to the left with the nose towards the mattress. When the posterior hole was reattached, which was easily identified on the basis of the preoperatively drawn vessels in close proximity, it was surrounded with soft interrupted laser lesions. At day 10, the thermal lesions around the 4 breaks were pigmented and the balloon was withdrawn. There was still a small residual gas bubble.

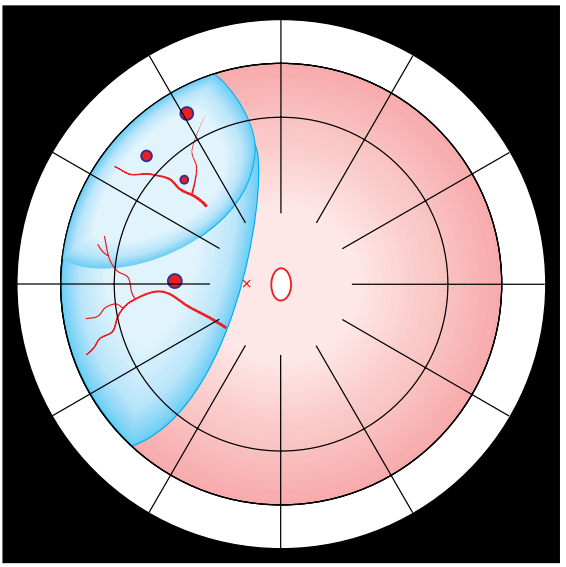


Fig. 10.**39 a** A lateral detachment with a group of breaks and a posteriorly located hole.

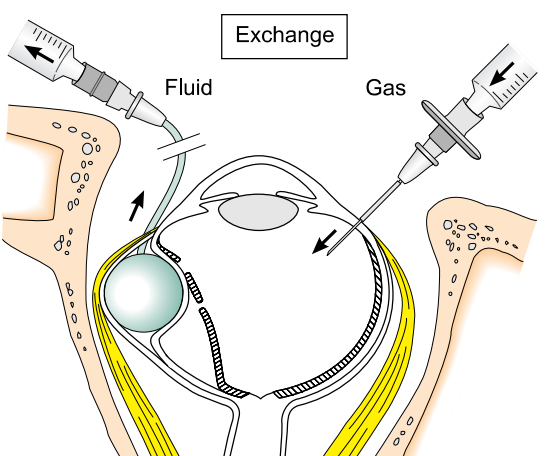


Fig. 10.**39 b** *Extended* balloon–gas procedure: 1. It was applied to inject 0.8 ml of CF_4 without drainage of subretinal fluid in a kind of fluid-gas exchange. 2. To tamponade the 3 more anterior holes.

? Did this imply restrictions for the patient?

▶ During the day no tamponade position was needed (the bubble ascended towards 12 o'clock), however, as long as gas was present, the patient was asked to sleep with the head on the side.

? Why?

▶
- To avoid the gas bubble covering the back of the lens (risk of cataract) or compressing the anterior chamber angle (risk of glaucoma) during the night.
- In addition, you might recall that such a patient can only fly on an airplane, if the gas bubble is 4 dd above the top of the disk.

Figure 10.**39c** demonstrates the retina 3 weeks postoperatively. After another week visual acuity had increased to 20/20.

In contrast to these good results, a bad experience which we had with a comparable detachment should be described. In this detachment, which was treated earlier, the expanding-gas operation had failed.

? Why?

▶
- Because after reattachment of the multiple tears by the gas bubble, it became apparent that it was no longer possible to identify all of the breaks and consequently to coagulate all of them sufficiently.
- As a result, when the gas bubble receded, redetachment occurred.
- After a 2nd gas operation—to be on the safe side—larger areas of reattached retina were covered with thermal lesions and, due to these extensive posterior scars, the patient perceived a **disturbing scotoma.**

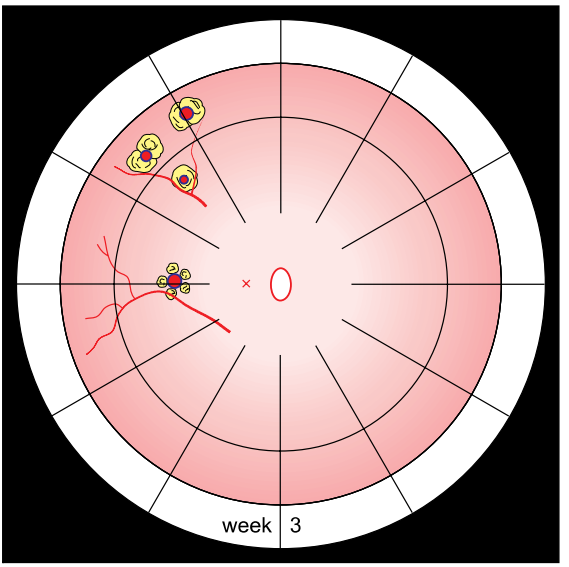


Fig. 10.**39 c** Fundus after 3 weeks: The anterior holes were cryopexied and tamponaded by the parabulbar balloon, which was part of the *extended* balloon–gas procedure, applied to inject in addition 0.8 ml of CF_4 without prior drainage. After the gas bubble had expanded to 1.5 ml, the patient was positioned flat and the head was tilted to the left with the nose towards the mattress. The posterior round hole was reattached the next day. It was detected behind the gas bubble by the neighboring vessels, depicted prior to surgery, and surrounded with soft interrupted laser lesions. After 4 weeks visual acuity had increased from 20/25 preoperatively to 20/20. The retina remained attached during the subsequent 10 years.

Consequently, the following should be borne in mind:

? Prior to a gas operation, precise documentation of multiple breaks is mandatory. Why?

▶ Because only after doing so, you will be able to detect and treat all of the breaks, and this is a premise for success with the gas operation.

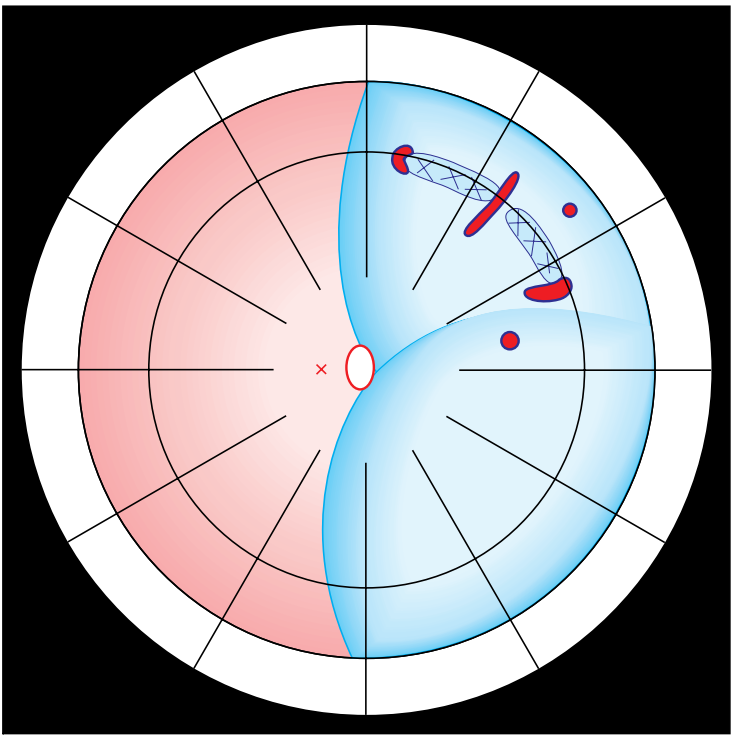


Fig. 10.**40 a** A group of anterior and posterior holes within an extension of 1 quadrant. The macula is attached, and visual acuity is 20/20.

10.6.2.2 Group of Anterior and Posterior Holes Extending over 1 Quadrant

This difficult detachment could actually represent the indication for an external pouch operation without drainage (Fig. 10.**40a**). As you will recall, the results with this procedure are favorable, however, the operation is laborious and time consuming (see Part 1, Chapter 8.8, pp. 181–190).

If, however, you are willing to accept the possible complications of the expanding-gas operation and you are not intending adding a vitrectomy with its own morbidity, this detachment represents an indication. This was actually the case for us. After cryopexy

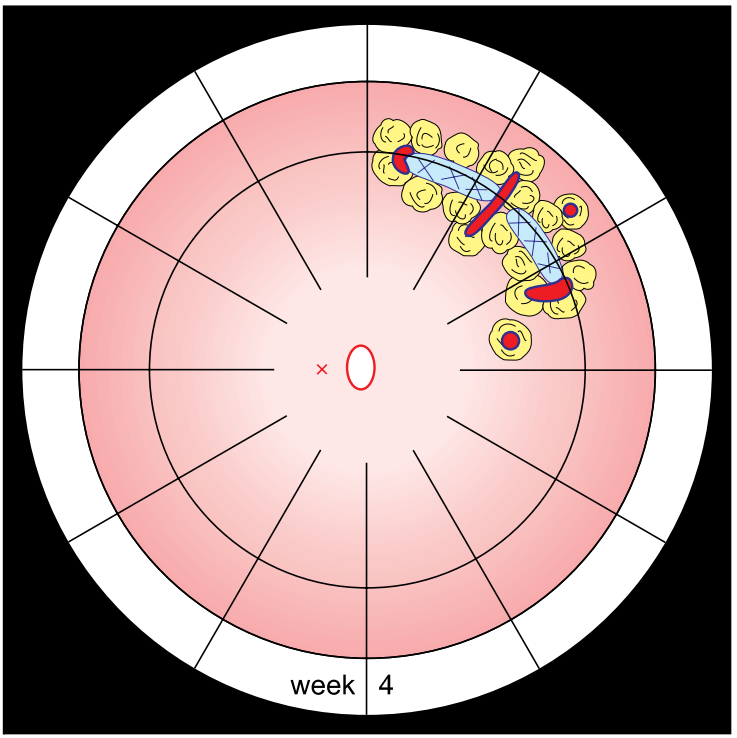


Fig. 10.**40 b** Fundus 4 weeks later: After cryopexy of the tears, the *basic* balloon–gas procedure was performed by placing a parabulbar balloon at 12:30, and by a fluid–gas exchange 0.7 ml of C_2F_6 was injected without drainage. After expansion of the gas, the bubble tamponaded the entire group of breaks and the balloon was removed. The patient was positioned with the head turned to the right and elevated for 45°. After disappearance of the gas bubble all of the holes appeared to be sufficiently sealed off with thermal lesions. No redetachment occurred. After 3 weeks visual acuity was again 20/20. New tears at 8 and 10 o'clock, which had developed after 4 and 6 months, were sealed off with laser lesions. The retina remained attached during the 5-year follow-up.

of the tears, the basic balloon–gas procedure was performed. A parabulbar balloon was placed at 12:30, and 0.7 ml of C_2F_6 was injected. After 2 days the gas bubble had expanded to 2.3 ml. On the 1st post-

operative day the balloon was removed, the patient was positioned with the head elevated for 45° and turned to the right. When the gas bubble receded, all of the tears were sufficiently sealed off with thermal lesions (Fig. 10.**40b**). Visual acuity that was 20/20 prior to treatment had recovered its original level 3 weeks after surgery.

During the 5-year follow-up at 4 and 6 months after surgery a horseshoe tear had developed at 8 and 10 o'clock. The tears were detected during the regular check-up and sealed off with laser lesions.

10.6.2.3 Conclusion

The expanding-gas operation is an ideal procedure for a group of breaks at different latitude not suitable for external buckling.

- **The key to sustained reattachment after a gas procedure is:**
  - Find all of the breaks and document them **preoperatively.**
  - Find them **intraoperatively** in detached retina.
  - Find them **postoperatively** behind the gas bubble in reattached retina.
  - Apply a **minimum of coagulation *around all of the breaks,*** but as much as is needed to provide sufficient scarring, induced by cryopexy or laser coagulation, for sustained reattachment after disappearance of the gas bubble.

A certain drawback of the gas procedure is that the patient's head has to be positioned for at least 1 week, and travelling on an airplane is restricted until the gas bubble occupies less than 10% of the eye (the meniscus of the gas bubble should be 4 dd above the top of the disk). The pouch operation does not imply these restrictions.

If, however, you are confronted with a group of holes at different latitude as in Figure 10.**40**, but instead located in an inferior position, a pouch operation is preferable, if you intend to avoid an intraocular surgery.

Another precondition for the expanding-gas operation is clear optic media. If, however, clear media are not present, it is another indication for the pouch operation, under the proviso that you prefer extraocular surgery. A primary vitrectomy with expanding gases or silicone oil, possibly combined with a lensectomy,

would represent an alternative. However, this is a more invasive and consequently more morbid procedure.

Over time you will develop more skills and your own criteria for selecting the adequate procedure being as minimal as possible for each type of these difficult detachments.

10.6.3 Posterior Holes

10.6.3.1 Fundamentals for the Gas Technique

First of all let us recall: A full-thickness macular hole as cause of a detachment represents the exception, as discussed in Part 1 (see Chapter 5.2.1, pp. 71–73). In 2 series, each of 1,000 retinal detachments, there was only 1 detachment in which the primary hole was close to the fovea, i.e., paracentral and this was in a myope. However, a posterior hole can be located elsewhere within the posterior pole, i.e., either nasal or temporal to the disk. This represents an area relatively inaccessible to scleral buckling and, in addition, buckling may jeopardize visual function.

? Why?

▶ Because a buckle in posterior retina may distort the macula or embarrass the optic nerve.

You will ask:

? How is the posterior pole defined, i.e., in horizontal and vertical direction in millimeters?

? How large should the retinal arc of a gas bubble be to cover the posterior pole and tamponade a retinal break in this area and still allowing for imperfect positioning of the posterior pole and permitting a latitude of movements so that the patient may still eat and go to the toilet?

▶
- The answer to these questions was worked out in a study done by Lincoff and his group, to which the author belonged at that time [48].
- Spontaneous holes in the posterior pole tend to be small, although they appear deceptively large through the magnification of an ophthalmoscope.

- Spontaneous holes did not exceed the size of the disk, and most were **less than 5° (1 mm) in their greatest extent**.
- There was 1 iatrogenic tear, 20° (4 mm) in diameter, that occurred during intravitreal surgery.

The posterior pole of the globe that is relatively inaccessible to conventional scleral buckling constitutes a horizontal oval (Fig. 10.**41**). The upper and lower borders of this oval are the temporal vessels. The temporal limit is 2.5 dd beyond the macula and the nasal limit is 1 dd beyond the disk.

- The posterior pole consists of:
  A circular area around the macula with a radius of 20° (about 4 mm), to which is added a nasal crescent of 15° (3 mm).
- The posterior pole begins in an average eye:
  24 mm from the limbus temporally
  21 mm in the nasal meridian.
- To tamponade this area sufficiently requires
  a gas bubble that subtends an arc of at least 55° (about 11 mm).

? How large does the gas bubble have to be?

From a previous gas model, elaborated by Parver and Lincoff [47], we know that in the average eye with an internal diameter of 21 mm:

0.25 ml of gas covers 88°
0.5 ml of gas covers 106°
1.0 ml of gas covers 132° (Fig. 10.**42**).

We should realize that relatively small volumes of gas spread broadly across the polar cap of the eye, but disproportionately large increments are required to extend the arc towards 180° (Table 10.**3**).

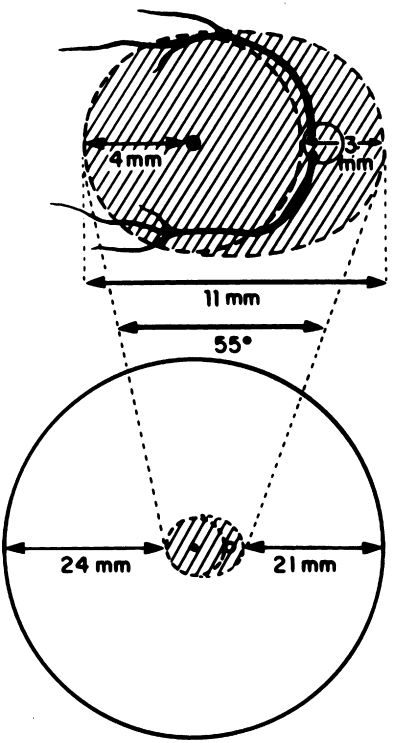


Fig. 10.**41** The inaccessible portion of the eye represents an 11 mm horizontal oval whose border is 24 mm from the limbus temporally and 21 mm nasally [48].

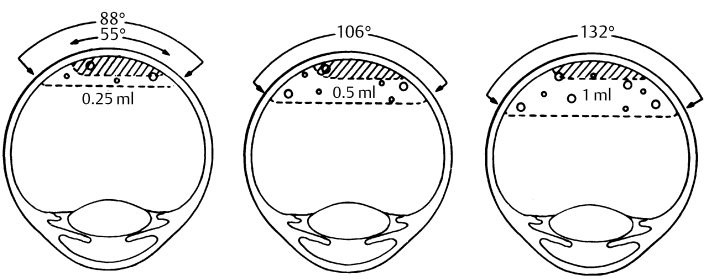


Fig. 10.**42** The posterior pole (striped) occupies a horizontal arc of 55°. 0.25 ml of gas provides a bubble with an arc of retinal contact of 88°, 0.5 ml contacts 106°, and 1 ml contacts 132° (see Table 10.**3**) [48].

Table 10.**3** Relationship of bubble volume to arc of bubble–retina contact in a vitreous cavity of 21 mm diameter

Bubble volume (ml)	Arc of bubble-retina contact (degrees)
0.25	88
0.50	106
1.00	**132**
2.00	168
2.40	180

- **However, in our clinical experience:**
  - **A gas bubble of 1 ml, that subtends an arc of 132°, has proved to be an adequate tamponade for a tear in the posterior pole.**
  - This provides a latitude for error in positioning or for voluntary excursions of:
    45° temporally (up and down) and
    31° nasally.

? But how large does the gas volume have to be in a myopic eye?

▶ The volume required has to be significantly greater and depends on whether the enlargement of the myopic eye is more spherical or in an axial elongation.

For example, the gas volume required to cover an arc of equal angular extent increases by 50% in a spherical eye with an internal diameter of 24 mm (15% larger than the norm). However, in a 27 mm myopic eye, the gas volume required increases by 100% (Fig. 10.**43**). The elongation of the eye, on the other hand, causes a smaller increase in volume, because only 1 axis is changed. An increase of 15% in axial length would require only a 15% increase in gas volume. However, in many myopes the axial elongation is accompanied by spherical enlargement, so that the effect of each must be added.

Let me explain this to you in an example: An eye with a transverse diameter of 27 mm and an axial length of 34 mm requires a 100% increase in volume plus 26% to compensate for the additional axial length.

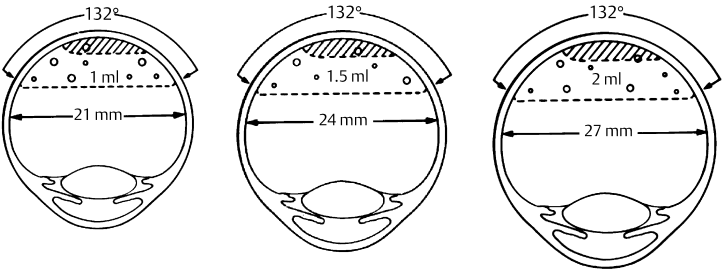


Fig. 10.**43** Spherical enlargement in the myopic eye requires greater amounts of gas to tamponade a retinal arc of equal angular extent: 1 ml of gas is required for an average eye of 21 mm, but 1.5 ml of gas for a 24 mm eye and 2 ml for a 27 mm eye [48].

Here is something to be considered as well:

The volume of a **posterior staphyloma** can, for the most part, be disregarded in estimating the gas volumes required to tamponade the posterior pole.

? How about the duration of a gas tamponade in these eyes?

▶ To provide a strong enough thermal adhesion (see Part 1, Chapter 7, pp. 93–124), it is desirable that the gas tamponade lasts for at least 8 days.

Since intraocular gas constantly diffuses across the blood aqueous barrier, it is necessary to **start with a larger volume of gas so that it will not diminish below 1 ml at 8 days.** This is the situation for the emmetropic eye.

● If, for example, **0.6 ml of C_2F_6** (a gas with an expansion coefficient of 3.3 and a half-volume time of 10 days) were injected **with a balloon–gas procedure without prior drainage,** it could be expected to
expand to
> 1 ml in 24 hours,
2 ml in 72 hours, and slowly regress to
1 ml by day 9 to 12 (Fig. 10.**44**).
This would provide a latitude for error in positioning.

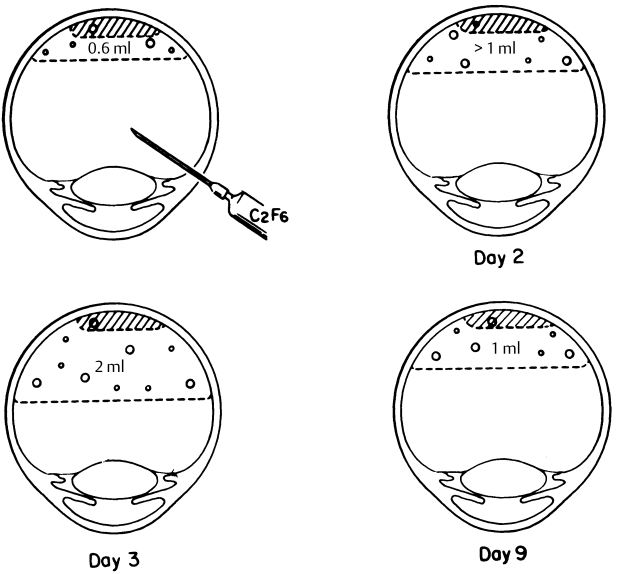


Fig. 10.**44** The effect of injecting 0.6 ml of C_2F_6 without drainage of subretinal fluid. The gas bubble expands 3.3 times by day 3 and provides an adequate tamponade of the posterior pole with the patient in prone position for 9 days [48].

? Another question: How has the patient to be positioned?

▶ Face-down in a prone position for 8 to 11 days, which is tolerated by a very determined and disciplined patient who, in addition, has no neck problems.

However, for those *patients who cannot tolerate such prolonged positioning, the alternative would be a perfluorocarbon gas bubble that fills more than half of the eye, i.e., that will tamponade the posterior pole when the patient is in any position except face-up.*Such a patient can sit up and walk about when awake and sleep on either side. In such a patient when using the balloon-gas procedure, a bubble of 0.9 ml of C_4F_{10} (a gas that expands 5 times and has a half-volume time of 45 days) can be injected [30]. By the 2nd day the bubble can be expected to fill more than half the volume of the eye. On the 3rd

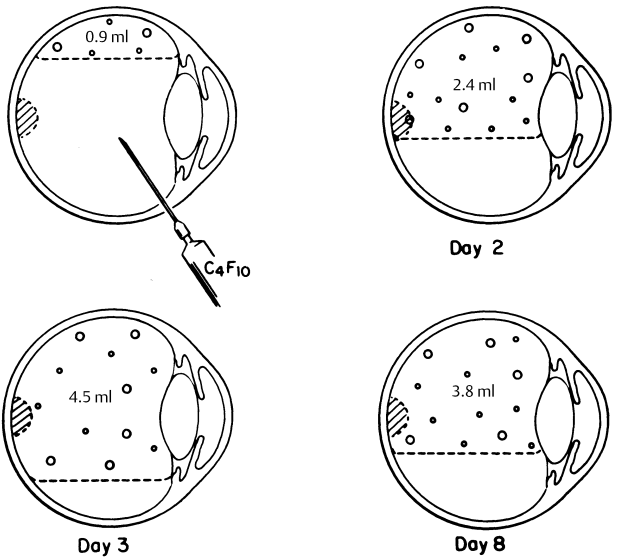


Fig. 10.**45** Injecting 0.9 ml of C_4F_{10}, a gas that expands 5 times, provides a bubble greater than the half-volume of the eye for more than 8 days and eliminates the need for the patient to maintain a sustained prone position, otherwise needed to tamponade the posterior pole [48].

day, at the time of maximal expansion, it should have a retinal arc of 270°. After that it will decrease in size, but—and this is essential—on the 8th day it can be expected to still cover at least 228°, i.e., *to overlap the posterior pole by about 5 mm* (Fig. 10.**45**). *However, the upright position of the head has still to be changed to a bent forward position most of the time to prevent the gas bubble from covering more than 1/3 of the lens (cataract!).*

? The next questions you might pose are:
- **How do you coagulate a hole at the posterior pole?**
- **Are there special precautions to be taken?**

▶ It is advisable to apply soft and interrupted laser lesions and to select the yellow or at least green wavelength of the laser.
Recall that these scars will subsequently enlarge, especially in a myopic eye (visual function!).

10.6.3.2 Examples

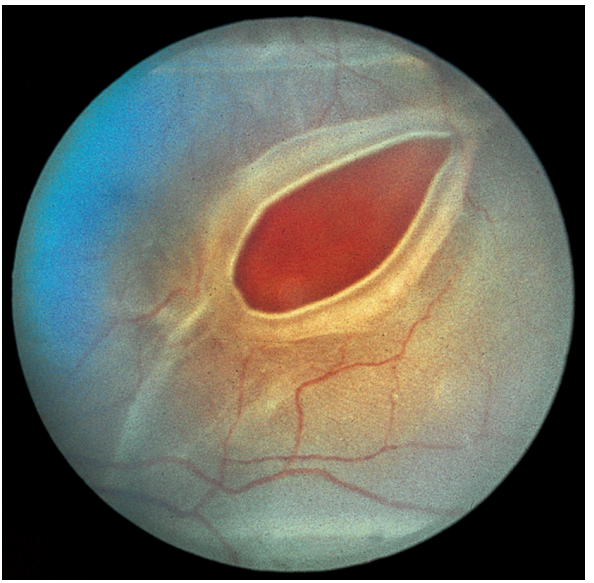
We started using an expanding SF_6 gas bubble for treating a posterior hole 25 years ago [17].

▶ The 1st patient with a large posterior tear, treated with SF_6 in 1975

An almost total detachment had a large spindle-shaped posterior tear with slightly rolled-over edges which was located temporally to the macula (Fig. 10.**46**, Top). This 34-year-old patient was treated in 1975 with drainage of subretinal fluid to enable the injection of a large gas bubble of 1.3 ml of SF_6. At that time neither the straight-chain perfluorocarbon gases (with an expansion potential larger than that of SF_6), nor the balloon–gas procedure were available. After SF_6 had expanded to a bubble of 2.6 ml and a face-down position was sustained, the large posterior tear was reattached.

With the patient sitting at the slit lamp, the tear was visible below the meniscus of the gas bubble (Fig. 10.**46**, Bottom). The large tear was treated with more than sufficient laser lesions because today, 25 years later, we would have applied softer and fewer interrupted laser lesions. However, this was our first patient treated with the new expanding-gas technique and this was the reason why the entire area of the thickened edges of the tear was covered with 2 rows of interrupted laser lesions. The patient had to sustain a face-down position for about 1 week until the thermal lesions had become pigmented. After another 5 months visual acuity had increased to 20/30.

Fig. 10.**46** *Top:* An almost total detachment with a large spindle-shaped posterior tear with slightly rolled-over edges located temporal to the macula. Visual acuity was counting fingers. *Bottom:* The 34-year-old patient was treated in 1975 with the expanding gas SF_6. After drainage, 1.3 ml of SF6 were injected. After the gas had expanded with the patient in prone position, the tear was reattached and surrounded with laser lesions. Today, 25 years later, we would apply only 1 row of interrupted and softer laser lesions. After 5 months visual acuity had increased from counting fingers to 20/30. ▷



▶ A patient with a posterior hole, treated with a perfluorocarbon gas, the basic balloon-gas procedure and without drainage 9 years later

This was a total detachment in a myopic eye, but with a parafoveal hole, an infrequent finding (Fig. 10.**47**, Top).

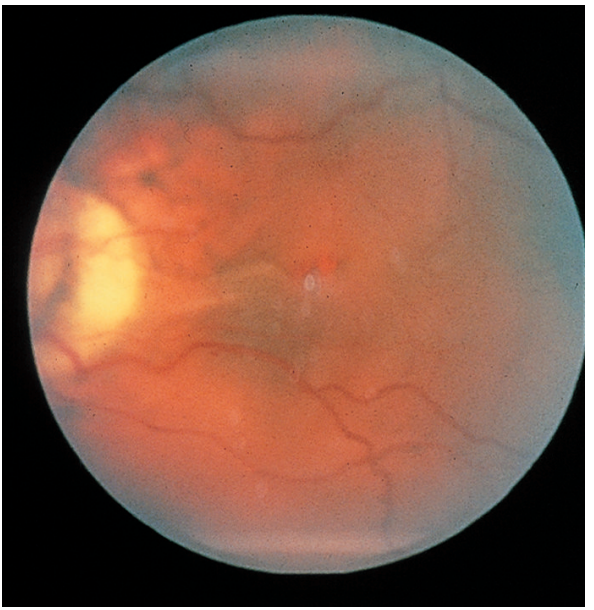
- **The expanding-gas operation was used as well** [27], **but:**
  - Without drainage of subretinal fluid.
  - This was made feasible by integrating the basic balloon–gas procedure.
  - Instead of SF_6, a perfluorocarbon gas was injected.

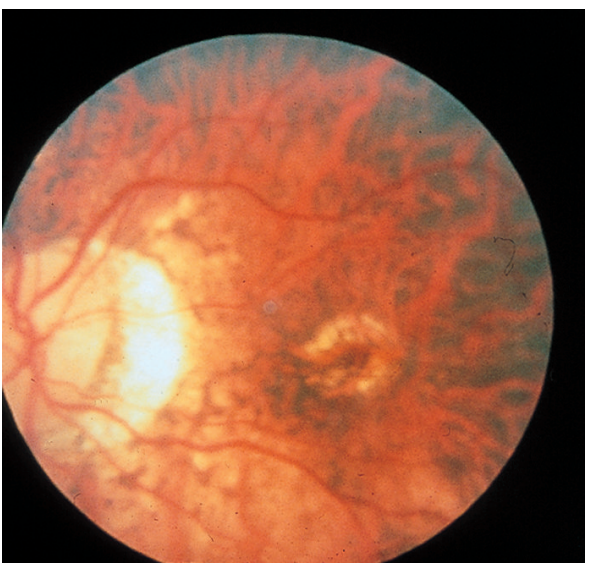
After compression with the parabulbar balloon, 0.9 ml of C_3F_8 were injected without prior drainage.

- The patient was positioned upright during the gas expansion.
- The moment the descending gas bubble had covered the macular area, the entire retina reattached.

However, **the treatment of this hole, because it was so close to the fovea, was deferred** (since treating it with laser coagulation would result in a central or paracentral scotoma) **until the patency of it was re-confirmed by the recurrence of an inferior detachment** at the moment the meniscus of the bubble receded above the hole.

Fig. 10.**47** *Top:* This myopic patient with a total detachment, a parafoveal hole, and a visual acuity of hand movements was sent to us in 1984. By applying the *basic* balloon–gas procedure, 0.9 ml of C_3F_8 was injected without prior drainage. The patient kept an upright position until the expanding gas bubble approached the hole which resulted in reattachment of the retina. But laser treatment was deferred until the gas bubble ascended and the retina redetached. Thereafter, the patient was positioned prone, resulting in reattachment of the parafoveal hole which only after this confirmation was lasered with soft interrupted lesions. *Bottom:* The fundus 11 years later. Note how the laser lesions had become confluent and the posterior scar expanded in this myopic eye. Visual acuity was 20/100. ▷





Upon this confirmation, the parafoveolar hole was again tamponaded by repositioning the gas bubble over the macular area. To achieve this, the patient was placed in a face-down position. With the hole again reattached, it was treated with 1 row of soft interrupted laser lesions. In the next Figure (Fig. 10.**47**, Bottom) you see this patient 11 years later: In the meantime the single row of interrupted laser lesions had become confluent and the scar expanded (myopic eye!), but visual acuity was still 20/100.

10.6.3.3 Conclusion

To put into perspective the expanding-gas operation without vitrectomy, we think it should be the 1st operation for tears in the posterior pole.

? Why?

- Because it is less morbid than posterior buckling or a primary vitrectomy with gas.
- The merits of the gas operation without vitrectomy are the favorable postoperative visual results early and late.

If, however, the gas operation fails—which will be the case if traction is stronger than the thermal adhesion induced or if the tissues available in the posterior pole are atrophic or incapable of responding to coagulation with an adhesion –, then buckling, however difficult, or vitrectomy may be appropriate.

10.6.4 Diagnostic Gas Bubble and Gas-Exchange Techniques

10.6.4.1 Rationale of Diagnostic Gas Bubble Technique

An intraocular expanding bubble of a perfluorocarbon gas can be of help to find the level of a retinal break in a detachment in which a break could not be found by the usual examination techniques. The method for finding such a break with an expanding (descending) or regressing (ascending) gas bubble is arduous and time consuming for the patient. However, it is more sensible and less hazardous than multiple buckle operations or a vitrectomy, especially in a patient

with a clear lens. But the diagnostic gas bubble technique is only justified when prospective segmental buckling has failed to close an undetected break [49].

- **The diagnostic gas bubble technique provides twice the chance to locate the horizontal meridian of an undetected break:**
  - During the phase of expansion, as the meniscus of the bubble is **descending**.
  - During the phase of regression, as the meniscus of the bubble is **ascending**.

? How should one proceed when applying the diagnostic gas bubble technique?

▶ Initially you will observe the expanding gas bubble with the patient's head in a vertical position.

? What do you have to watch out for during the *descending phase* of the gas bubble?

▶ The moment when its meniscus crosses the horizontal meridian of the undetected break, because then the **inferior retina will reattach.**

If, at this moment, you have missed the opportunity to detect the break in the nasal or temporal periphery of this meridian or if you are still in doubt about the presence of a posterior break (risk of substantial loss of central vision after laser treatment), you have a second chance to detect or ascertain the presence of the break when the gas bubble regresses.

? What do you have to watch out for during the *ascending phase* of the gas bubble?

▶ The moment when its meniscus approaches and crosses the meridian of the break, because then the **inferior retina will redetach.**

By now you will have plotted the exact location of the break. By positioning the patient's head face-down, the detected break will be tamponaded again by the gas bubble, reattach and be ready for laser treatment.

? But what is essential when applying a diagnostic gas bubble, i.e., during the descending or ascending phase?

- To study the retina with the patient in a sitting position, at least twice per day to determine:
  - Where the exact location of the meniscus of the gas bubble at the retina is?
  - If the inferior retina, which is not covered by the gas bubble, is detached or already reattached?
- To explain to the patient that he/she should cover the fellow eye several times a day, and question:
  - **Did the superior field return (descending phase)?**
  - **Did it disappear again (ascending phase)?**

To define precisely the moment when the visual field disappears again, it might be even helpful to patch the fellow eye.

? Why?

Because then the patient will perceive the very first moment when the hole is no longer tamponaded, i.e., the retina will redetach, resulting in loss of visual field.

Another question that might cross your mind:

? How has the patient with a diagnostic gas bubble to be positioned?

- **During the day** there are no restrictions, i.e., the patient can sit, stand, or walk about.
- **During the night** there are restrictions, i.e., when going to sleep the head has to be elevated for 45°.

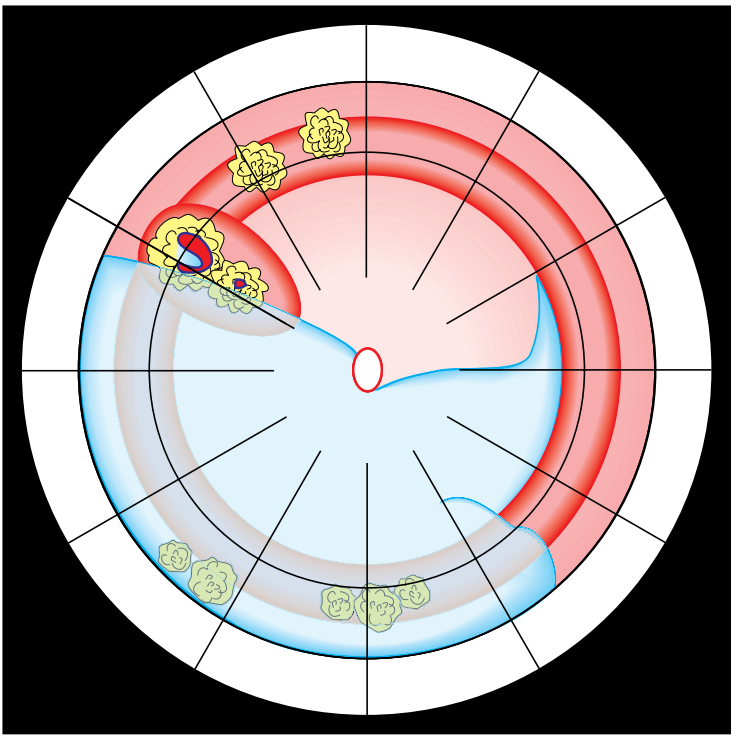


Fig. 10.**48** Use of a diagnostic gas bubble (descending or ascending) to find a break in a detachment (findings documented by H. Lincoff, M.D., New York): **a** Redetachment had occurred after 2 cerclages, drainage, a radial buckle, and coagulation in various areas. A break could not be found.

10.6.4.2 Clinical Application

▶ **Example**

The diagnostic gas bubble technique will be presented by the findings in the following patient (Fig. 10.**48a**): After 2 cerclages, radial buckling, and drainage the 3rd redetachment had occurred. In the detachment, extending from 2 over 6 to 10 o'clock, no break could be found. However, it seemed likely that the undetected break was between 8:30 and 10 o'clock in the area that had been previously coagulated and buckled 3 times. It was estimated that a gas bubble

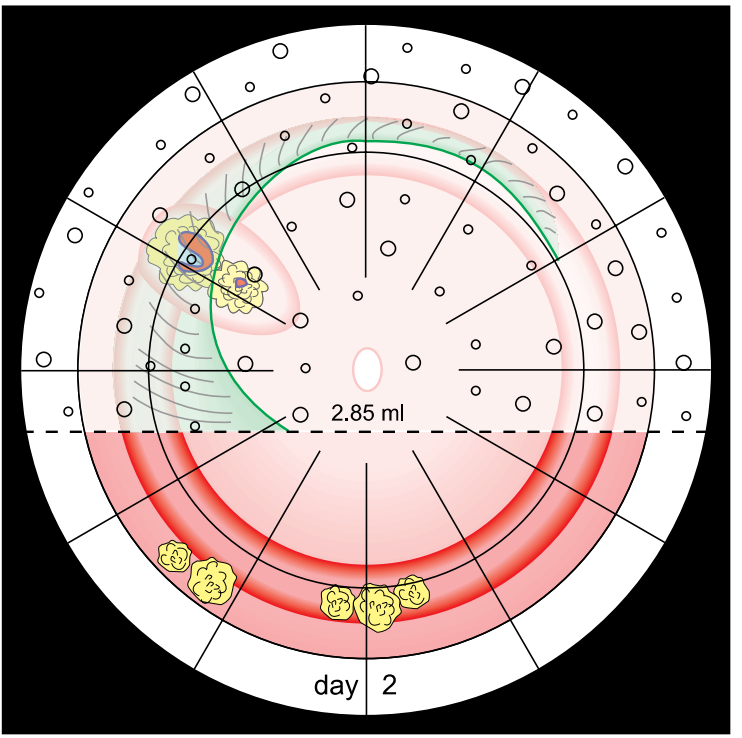


Fig. 10.**48 b** To detect a break, the diagnostic gas bubble technique was used, an expanding gas (0.9 ml of C_2F_6) was injected into the vitreous, and over 2 days, it expanded to 2.85 ml: The patient slept in an elevated position (45°), and was able to walk about during the day. *When the descending gas bubble crossed the 10 o'clock meridian, the retina suddenly reattached.* The gas bubble made a vitreous membrane visible and therefore, leakage from the horseshoe tear was suspected.

of slightly less than 3 ml volume would be more than sufficient to tamponade the retina down to 8:30. Being up for the 4th operation, it was decided to inject 0.9 ml of C_2F_6 after prior drainage. Two days later the bubble had expanded to an estimated volume of 2.85 ml and the retina was reattached (Fig. 10.**48b**). After that as the gas bubble regressed, the retina remained attached until the 9th day

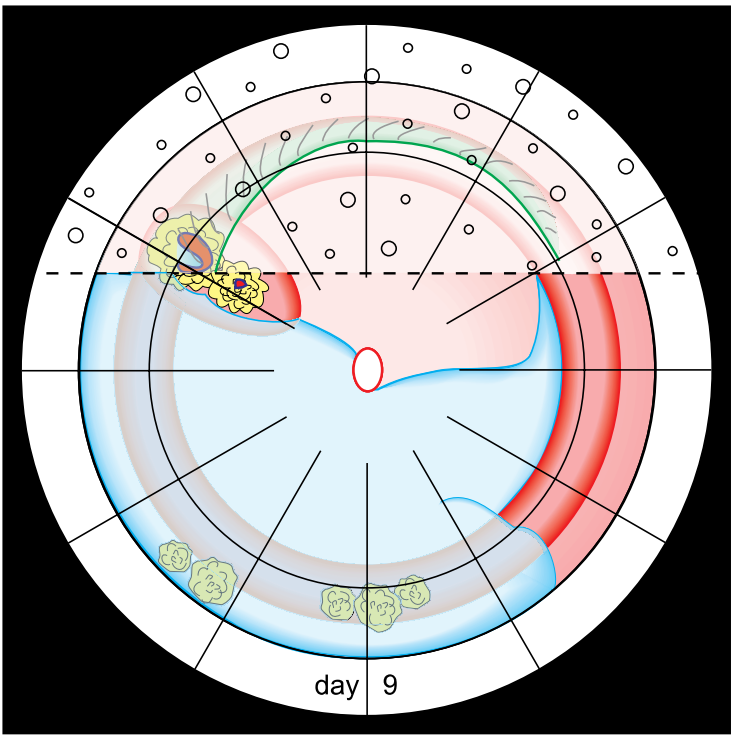


Fig. 10.**48 c** Up to day 9, the gas bubble had receded, and the meniscus ascended: *When the ascending gas bubble crossed the 10 o'clock meridian,* the patient suddenly reported a loss of the superior visual field; *the retina had redetached.* The leakage at the horseshoe tear was confirmed, and could now be treated.

when the meniscus had crossed the radial buckle at 10 o'clock. Suddenly the patient, alerted to watch out for this moment, reported a loss of the superior field. The inferior retina had redetached (Fig. 10.**48c**).

? But what did we learn by this sequela?

▶ That at the meridian of **10 o'clock** the leaking break had to be located. It was concluded that a vitreous membrane, which had been made evident by the gas bubble, was holding open the horseshoe tear in spite of being buckled.

The subsequent treatment consisted of a vitrectomy, which was especially aimed at the area of the radial buckle, resulting in retinal reattachment. The reattached horseshoe tear was sealed off with laser lesions and the retina remained attached.

? Which additional information did the diagnostic gas bubble provide, besides detecting the leaking tear?

▶ It provided the precondition to perform a more directed vitrectomy, which was essential for this eye already injured by 4 preceding operations.

The favorable visual results of 20/50 after 1 year were more than to be expected after multiple reoperations. It might be testimony to the low morbidity of the extraocular and more directed intraocular procedures performed several months apart.

Here are more questions you might raise:

?
- **How is the volume of an expanded diagnostic gas bubble to be increased by larger amounts, whilst still preserving the benefits of a slow expansion, i.e., its diagnostic potential?**
- **How can this be achieved with only 1 injection, i.e., avoiding repeated small intraocular gas injections?**

▶ Apply the gas-exchange technique, as suggested by **Coleman** [30].

? How is it done?

▶ Here is how.

10.6.4.3 Gas-Exchange Techniques

▶ **1. To induce a *slow increase* of a gas bubble**

- **The advantages of this technique are:**
  - A substantially larger diagnostic gas bubble can be obtained, when the expanded volume appears to be too small for tamponade and you want to avoid repeated smaller gas injections.
  - If, for other reasons, a larger gas tamponade is required and you want to avoid the alternative, a prior vitrectomy, to obtain this larger intraocular space.

- **The gas-exchange technique is as easy as this:**
  - **Withdraw expanded** gas into a syringe from the intraocular gas bubble.
  - **Replace** it with an equal volume of **unexpanded** gas.

▶ **2. To induce a *faster decrease* of a gas bubble**

- **Withdraw expanded** gas into a syringe, already filled with air or Xenon gas.
- **Replace** it with an equal volume of by now **diluted** gas.
- Repeat this several times (while ascertaining that the tip of the needle is within the gas bubble) to exchange most of the perfluorocarbon gas.

With both techniques, do not forget to check the central artery for pulsation before sending the patient off.

10.6.4.4 Conclusion

The diagnostic gas bubble technique for finding a retinal break by using the descending (expanding) or ascending (regressing) gas bubble is arduous and time consuming for the patient, as well as for the physician. However, this gas technique can be justified as a primary procedure if the break is thought to be in the posterior pole or at a staphyloma.

? Why?

- Because in this situation a prospective buckling would be difficult and more morbid.
- A vitrectomy with a gas bubble would be more morbid than the application of a diagnostic gas bubble alone.

The 1st option of the gas-exchange technique, i.e., augmenting an intraocular gas bubble without drainage or vitrectomy, raises the limits of a 2nd gas injection. With this technique it becomes feasible to fill even highly myopic eyes with a large volume of gas with 2 injections and without the risks of draining subretinal fluid or adding a vitrectomy.

- In this situation the **gas-exchange technique reduces the trauma** which would be inflicted by multiple intraocular gas injections, otherwise needed, and it eliminates the additional time required for separate gas injections to increase the volume of an intraocular bubble.

- The **diagnostic gas bubble technique,** by using its descending or ascending phase, provides another tool to **avoid extensive prospective buckling or a vitrectomy.**

If in these difficult detachments the diagnostic gas bubble technique is successful in plotting the location of the undetected break, a limited, i.e., minimal, treatment with fewer complications becomes feasible which can provide conditions for more favorable long-term visual results.

10.6.5 Clinical Study

You might wonder what the results will be when using the expanding-gas operation without vitrectomy for treating difficult detachments. To provide this information, a prospective study, carried out between 1981 and 1984, will be presented [27].

10.6.5.1 Patients and Expanding-Gas Operation

A total of 51 difficult retinal detachments were treated by an expanding perfluorocarbon gas, injected into the vitreous; this was done without prior drainage in all but 6 eyes. In none of the patients was a vitrectomy performed. The expanding-gas operation was chosen because the detachments were not suitable for scleral buckling. The detachments were divided into 4 categories according to the level of difficulty:

Giant tear: 23
Group of breaks at different latitude: 9
Posterior hole(s): 16
Doubtful macular hole: 3

The follow-up of the patients was 12 to 38 months (mean 20 months). The mean age was 47 years, and of the patients with a giant tear 39 years.

Here are some characteristics of the detachments: 13 were reoperations, 6 aphakic, and 3 were perforating injuries. As depicted in Table 10.**4**, myopia was present more often in eyes with posterior hole(s) or in which no hole could be found. In the 51 detachments the preoperative grade of PVR was not remarkable, i.e., in more than half of the patients there was only PVR grade A or B (Table 10.**5**). With the giant tears, in 6 patients the tear extended for 1 quadrant, in 6 patients it extended between 1 and 2 quadrants, in 10 patients between 2 and 3 quadrants, and in 1 patient the tear extended for 350° (Table 10.**6**).

Table 10.**4** Characteristics of 51 retinal detachments treated with perfluorocarbon gases

Category	n	Myopia	Reoperation	Aphakia	Perforating injury
Giant tear	23	11	3	5	2
Group of breaks at different latitude	9	7	1	1	–
Posterior hole(s)	16	13	8	–	1
Diagnostic gas tamponade	3	3	1	–	–
Total	51	34	13	6	3

Table 10.5 Grade of PVR in 51 detachments before treatment with perfluorocarbon gases

Category	n	A	B	C1	C2	C3	D1
Giant tear	23	2	17	1	1	1	–
Group of breaks at different latitude	9	4	2	1	–	–	1
Posterior hole(s)	16	6	–	1	1	–	–
Diagnostic gas tamponade	3	1	–	–	–	–	–
Total	51	13	19	3	2	1	1

Table 10.6 Characteristics of 23 giant tear detachments treated with perfluorocarbon gases

Extent of giant tear	n
1 quadrant	6
> 1–2 quadrants	6
> 2–3 quadrants	10
350°	1
Additional breaks beyond giant tear	6

? Which perfluorocarbon gas was used for each category of tear?

▶ The selection of the perfluorocarbon gas depended upon the size and the longevity of the bubble considered necessary:

- **CF_4 was preferred for:**
  Posterior holes.
- **C_2F_6 and C_3F_8 were selected for:**
  Giant tears
  Multiple breaks at different latitude
  Diagnostic gas tamponade.

After integrating the basic and as well the extended balloon–gas procedure in the expanding-gas operation, C_3F_8, a gas with an expansion coefficient of 4 and a half-life of 35 days, was applied less frequently.

As already described, the gas was always injected with the patient in supine position. In the presence of a giant tear with a rolled-over flap, the small gas bubble technique was applied to unfold the flap.

Table 10.7 Results of 51 detachments treated with the expanding-gas operation using various perfluorocarbon gases

Category	n	Initially reattached	Finally reattached
Giant tear	23	19	15 (65%)
Group of breaks at different latitude	9	9	5 (55%)
Posterior hole(s)	16	16	15 (94%)
Diagnostic gas tamponade	3	3	1 (33%)*
Total	51	47 (92%)	36 (71%)

* The gas bubble confirmed the nonrhegmatogenous nature of 2 other patients.

The backward rotation was used for a superior tear with a rolled-over flap and forward rotation for a rolled-over inferior flap. In giant tears special care was taken to apply cryopexy to the anterior portion of the lateral edges into the pars plana. The patients maintained the optimal tamponade position (head-up, face-down, or on the side) for 12 to 16 days (except 1 patient with a 350° giant tear), the time it takes to form a strong retinal adhesion. During the gas tamponade the patients were allowed to sit up, to eat and to walk to the toilet. The moment a tamponade position was no longer required, they were cautioned against assuming a supine position as long as a substantial gas bubble was present in the eye (cataract formation, glaucoma!).

10.6.5.2 Results

The overall reattachment rate of the 51 detachments treated with the expanding–gas operation was 71%. Each category, however, differed significantly and will consequently be discussed separately (Table 10.**7**).

▶ **Giant tears**

Of the giant tears, the largest group, 19 out of 23 were reattached initially by the expanding-gas operation and 8 redetached within the subsequent 6 months. After reoperation with conventional buckling, laser treatment and repositioning of the residual gas bubble, or cutting of a traction band with the YAG laser:

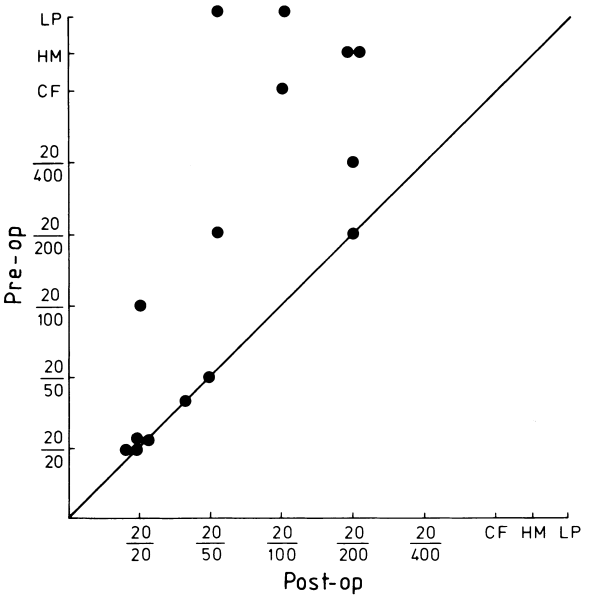


Fig. 10.**49** Visual acuity of 15 patients with *giant tears* which were reattached with the expanding-gas operation. Visual acuity improved (represented by marks above the diagonal line) or remained the same (marks on the line) in all of them during a mean follow-up of 20 months.

Final reattachment was obtained in 15 eyes (65%).
As mentioned, the 1 patient with the giant tear of 350° had received altogether 4 gas injections and had a gas tamponade for 10 weeks resulting in final retinal reattachment which was sustained for $17^{3}/_{4}$ years (see Fig. 10.**38**). Visual acuity was $^{20}/_{40}$ at that time.

Postoperative visual acuity
of the 15 patients with a reattached giant tear
either improved or remained the same (Fig. 10.**49**).

▶ Group of breaks at different latitude

Of the 9 multiple breaks at different latitude, all were initially reattached with the gas tamponade and cryopexy or laser applications. In 5 patients an additional buckle or the balloon, as part of the extended balloon-gas procedure, was used to tamponade the more

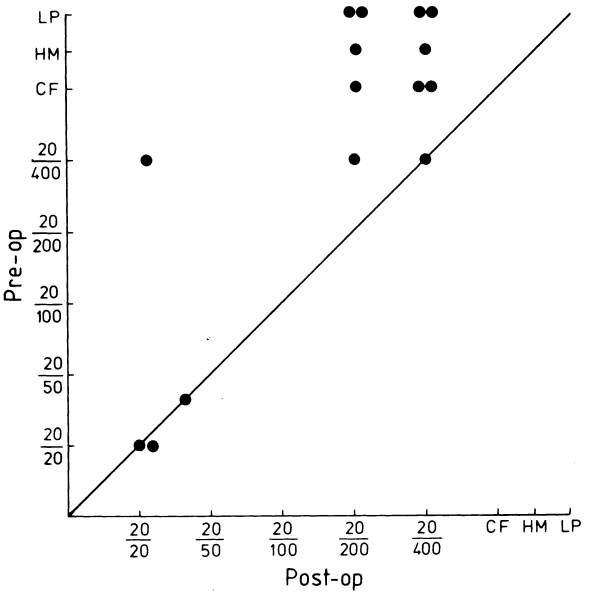


Fig. 10.**50** Visual acuity of 15 patients with *hole(s) in the posterior pole* which were reattached. Visual acuity improved or remained the same in all but 1 patient (mark below diagonal line). In this patient visual acuity decreased from 20/20 to 20/25 due to distribution of a preoperatively present vitreous hemorrhage, but was at 20/20 when tested with the retinometer (laser beam).

anterior breaks. In this situation the gas bubble was used to close the posterior break. However, in 4 patients the retina redetached: 3 times due to increasing PVR and once because of an additional break that was never found.

In 5 patients the retina was finally reattached.
The visual acuity improved or remained the same.

▶ Posterior holes

The 16 patients with posterior hole(s) were treated with the expanding-gas technique and laser coagulation of the hole. The gas tamponade was sustained for 10 to 16 days in patients selected for

prone positioning. For patients who required an upright position a larger volume of gas was used and it lasted for 20 to 40 days.

In 15 of the 16 patients the retina was reattached.
The visual acuity improved or remained the same (Fig. 10.**50**).

▶ **Diagnostic gas tamponade**

The 3 patients of the diagnostic category had holes in the macula that were either of full or partial thickness. **The "holes" in the macular area were tested with a descending gas bubble:**
In 1 patient the descending technique disclosed an additional break in the midperiphery and when this was secured with cryopexy, the retina reattached.
In the other 2 patients, high myopes with the detachment limited to the macular area, the gas bubble flattened the macula and drove the subretinal or intraretinal fluid only inferiorly. With absorption of the bubble the macular detachments assumed their previous extent, however, the elevations were flatter.

Visual acuity improved:
In the 1st patient from finger counting to **20/100**
In the last 2 patients from light perception to **20/800.**

10.6.5.3 Complications

The expanding–gas operation without vitrectomy is complicated by a **cellular infiltration of the gel**. This can be ameliorated by corticosteroids, but resolves only after the gas has absorbed.

● This is the reason why the **longevity** of the selected gas should be **no longer than needed**.

For most detachments the expanding-gas operation alone seemed as effective as a vitrectomy.

Only when preoperative PVR grade C was present
—as in 7 eyes—,
the gas operation proved to be inadequate:
In 5 of these 7 patients PVR progressed after gas injection. They might have done better with a vitrectomy.

10.6.5.4 Conclusion

- During the long-term follow-up none of the patients, treated with long-lasting gases of 2 to 5 weeks' duration, had developed late complications, such as glaucoma, keratopathy, or cataract.
- Postoperative visual acuity of the patients with reattached retina had remained the same or increased and did not deteriorate due to secondary complications during the long-term follow-up.

10.6.5.5 Reasons for Failure in Giant Tears

When treating a giant tear with a gas bubble of adequate size, it can press the tear back to its original position and retinal adhesion can be obtained with cryopexy or laser lesions. However, in every instance the extensive anterior edge of the tear, the operculum, remains under traction and consequently detached. To confine this detachment, the lines of coagulation are extended anteriorly on either side of the tear beyond the operculum to the **ora serrata. As we had learnt from an earlier series, this will not always suffice** [50]:

- As you might recall, we now extend the cryopexy lesions at the lateral edges of a giant tear up into the **pars plana**.

There are actually 3 avenues for failure, after the gas bubble has absorbed:

▶ **Lateral leak along the line of vitreous traction**

This is exemplified in the detachment with a large tear in Figure 10.**51a**. The lateral large tear with an extent of about 90° was reattached by the gas tamponade and the posterior and lateral edges sealed off with cryopexy lesions. On the 4th day after the bubble had receded, the tear started to leak laterally in inferior direction along the line of vitreous traction, already perceptible prior to surgery (Fig. 10.**51b**). If you were to detect this leak with a localized detachment before the entire large tear is redetached, you could treat it as a simple tear of small dimension.

? What might you consider now?

▶ A **radial sponge buckle with cryopexy and without drainage** beneath this tear (Fig. 10.**51 c**).

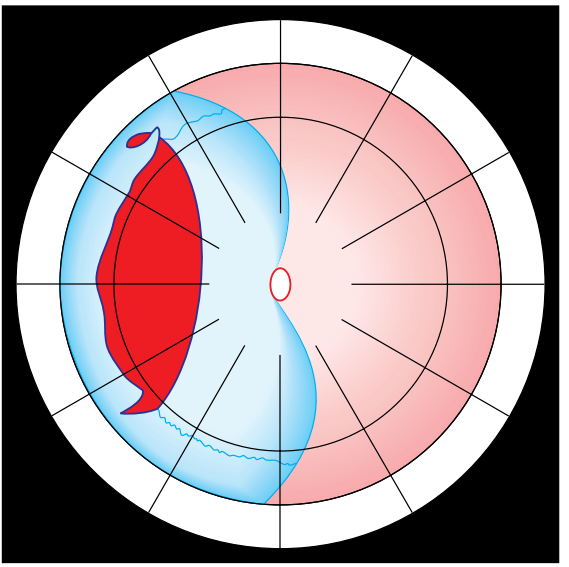


Fig. 10.**51 a** A retinal detachment caused by a 90° large tear.

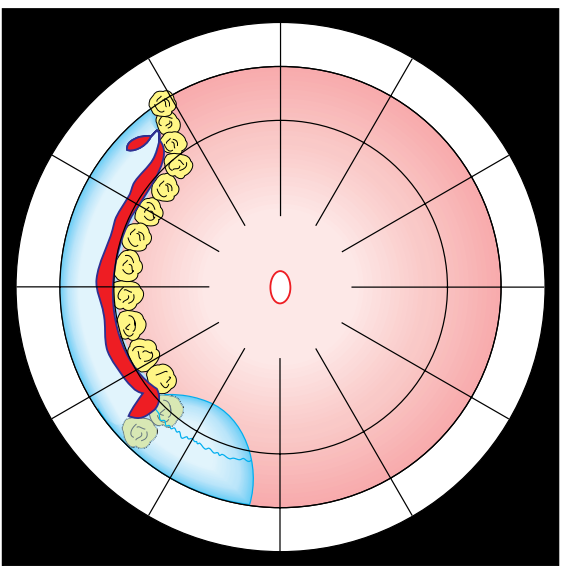


Fig. 10.**51 b** The posterior and lateral edges were sealed with cryopexy and a gas tamponade. On the 4th postoperative day the tear started to leak laterally along the line of traction, which was already present preoperatively. The detachment was recognized at an early stage, i.e., before the entire large tear redetached.

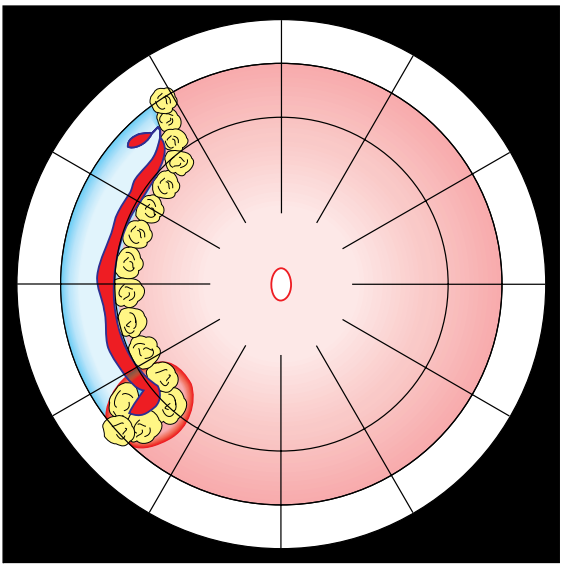


Fig. 10.**51 c** Reattachment was achieved with additional *cryopexy* lesions and a *radial sponge buckle* without drainage.

In the case of both sides leaking, usually days apart, then apply another radial sponge to the opposite edge of the tear. However, in this large tear presented to you, only the inferior edge had started to leak.

▶ Anterior leak by circumventing the anterior lateral line of coagulations

The giant tear, with an extension of about 120°, represented in Figure 10.**52a**, was reattached by using the expanding-gas operation without drainage. Postoperatively, redetachment started due to a leak. This time the leak was more difficult to counteract because the operculum lifted the ora serrata and, consequently, the leak was too anterior to be buckled (Fig. 10.**52b**). In this situation, subretinal fluid will dissect beneath the ciliary epithelium, circumvent the anterior cryopexy coagulations and cause an inferior redetachment.

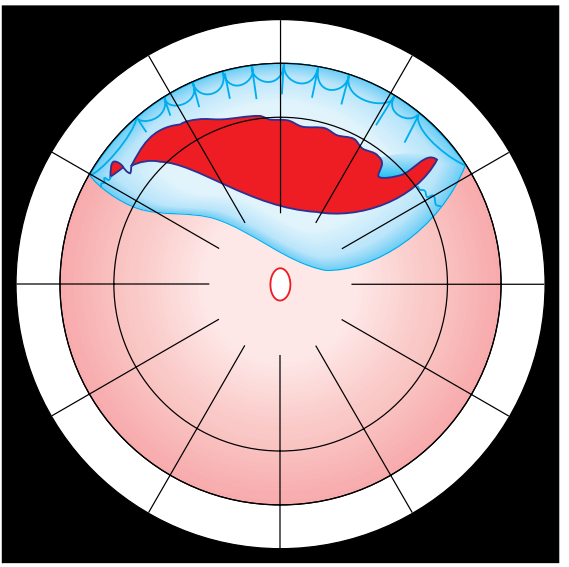


Fig. 10.**52 a** A retinal detachment caused by a superior giant tear of about 120° in extent.

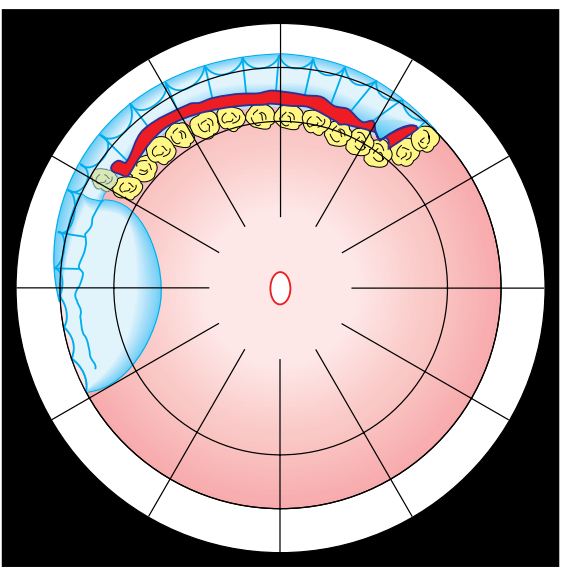


Fig. 10.**52 b** The posterior and lateral edges had been sealed off with cryopexy to the ora serrata and a gas tamponade. Traction from the operculum had lifted the ciliary epithelium and redetachment occurred by way of a progressive ciliary epithelial detachment that circumvented the lateral lines of coagulations.

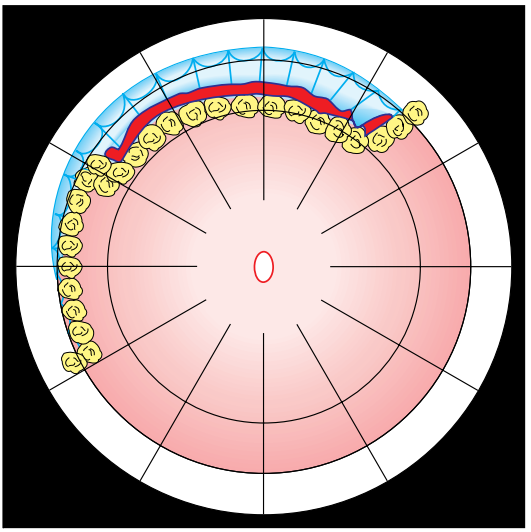


Fig. 10.**52 c** Reattachment was obtained by extending the line of *cryopexy* from 10 o'clock over 9 to 8 o'clock up into the pars plana, by a *gas injection without drainage* and positioning the gas bubble over the treated area until adhesions had formed. During surgery also a prophylactic cryopexy lesion was placed in the pars plana at 1:30.

? What should be done?

▶ The problem was overcome by adding **cryopexy** lesions to the adjacent anterior retina beyond the pars plana separation, injecting an expanding **gas bubble without drainage** and positioning it on the coagulated area until retinal adhesions had formed. After disappearance of the gas bubble, the retina remained attached (Fig. 10.**52c**).

Now the question you might have posed earlier can be answered:

? Why, when treating a giant tear, should you apply the cryopexy lesions into the pars plana?

▶ To counteract with the adhesions in the pars plana the threat of a subsequent anterior leakage—as just experienced—which originated from the operculum and extended into the pars plana beneath the ciliary epithelium.

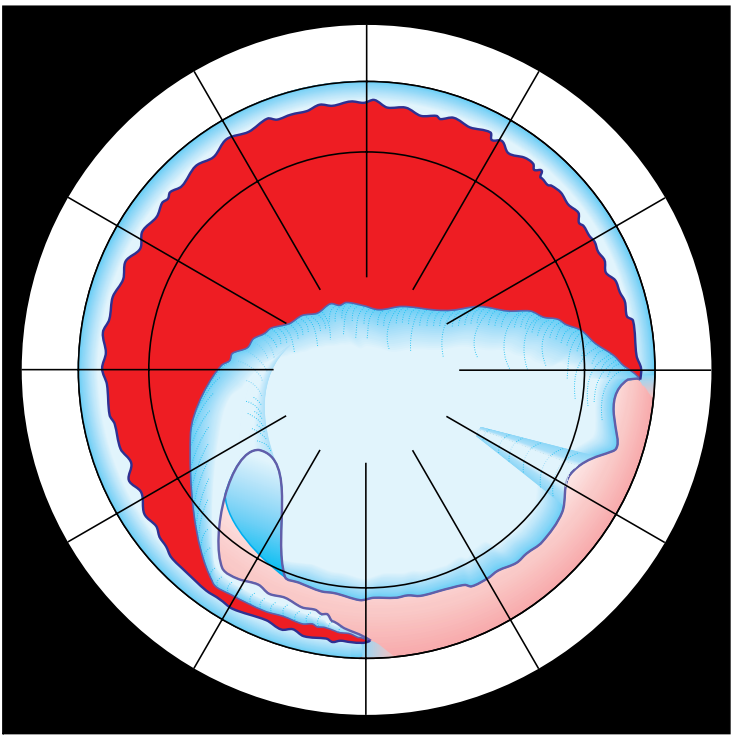


Fig. 10.**53 a** A retinal detachment caused by a 270° giant tear with a rolled-over posterior flap (patient treated by H. Lincoff, M.D., New York in 1975).

In the subsequent giant tears, in which we had extended the cryopexy lesions at the lateral edges of the tear into the pars plana, this prophylaxis seemed to work.

▶ Posterior leak due to a starfold

In Figure 10.**53a** you see a giant tear of 270° in extent with a rolled-over posterior flap. It was reattached by using the gas procedure (small gas bubble technique for unfolding the flap and then a large gas tamponade) and cryopexy. However, redetachment occurred due to a posterior leak. But this time the leak was caused by PVR, which is most difficult to overcome (Fig. 10.**53b**).

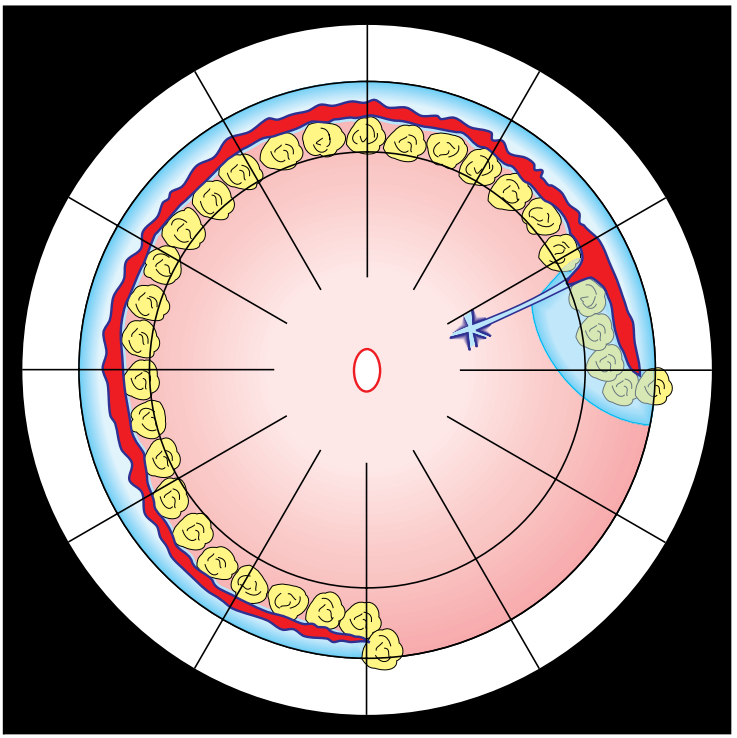


Fig. 10.**53 b** After unfolding the flap, the retina was reattached by the gas technique without prior vitrectomy, and the posterior edge of the giant tear was sealed off with cryopexy lesions. Redetachment occurred when the contracture of a posterior starfold lifted the posterior edge of the tear at 2:15.

? What might you consider now?

▶ If, however, PVR is limited to a single posterior starfold and its development is recognized in time, i.e., before the entire posterior edge of the giant tear is redetached, a **radial sponge buckle without drainage** beneath the leak might suffice. After **well-monitored cryopexy** to the posterior leaking edge at 2:15, a radial buckle was placed beneath the leak and the retina reattached (Fig. 10.**53c**).

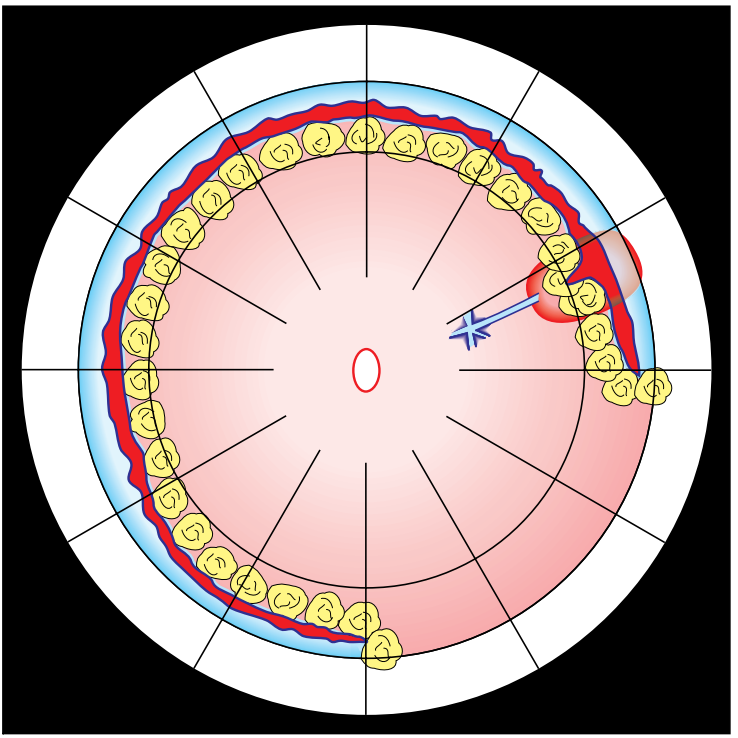


Fig. 10.**53 c** Reattachment was achieved by additional *cryopexy* and a *radial sponge buckle* in the area of the leak *without drainage* of subretinal fluid. The retina remained attached during long-term follow-up.

If, however, PVR is more extended (and this was the main reason for final failure in our series, treated between 1981 and 1984 without vitrectomy), vitrectomy with membrane peeling has to be added.

? Are there prophylactic measures to reduce the risk of cellular proliferation and to circumvent a reattachment of the *hyaloidal membrane* to the posterior retina, because this might result in the development of posterior starfolds?

1. Avoid traumatic surgery to reduce the cellular reaction of the vitreous.
2. Keep the cryopexy applications to a minimum.
3. Use a more rapid absorbing gas whenever feasible.
4. Apply the "rolling gas bubble technique" (discussed earlier in this Chapter) to prevent the reattachment of an already detached(!) posterior hyaloidal membrane.
5. If for special reasons you should decide upon a vitrectomy with a gas fill, make sure that the posterior hyaloid is excised completely.

? Why?

Because remnants of cortical vitreous would be pressed by the gas bubble against the retina, become adherent to it again, start to proliferate, and induce PVR—one reason for failure.

10.6.5.6 Conclusion

Considering the results of treating these 4 categories of difficult retinal detachments, it becomes evident that the expanding-gas operation in conjunction with the 2 types of the balloon-gas procedure represents a method of choice for breaks in the posterior pole.

Since no prior drainage or vitrectomy are needed, this technique inflicts minimal surgical trauma to these eyes:
15 of 16 detachments with a posterior hole were reattached without additional intraocular surgery.

In treating **giant tears, 15 out of 23 were reattached** with the expanding-gas technique, however, implying compliance by the patient and engagement by the doctor during the entire postoperative course.

If, however, the retina will be reattached after an expanding–gas operation, visual acuity will be favorable early and late.

- The results when treating a **group of tears at different latitude** with the expanding–gas technique
  can be discouraging, if all of the breaks have:
  - **Not been detected** and documented preoperatively and
  - **Not been sealed off sufficiently** with thermal lesions intraoperatively or postoperatively.

Consequently, the following should be recommended:

- **Do not inject a gas bubble into an eye with a detachment *because you did not understand* the detachment:**
  - Admittedly, the gas bubble will reattach the retina, but only temporarily if your treatment does not imply a rational approach.
  - And if you decide upon a diagnostic gas bubble, you have to know what you have to look for.

Consequently, apply an intraocular gas bubble only after a thoughtful evaluation. At this point it should cross your mind that this gas injection might already induce PVR, a development which will move this detachment into another degree of morbidity.

In brief:

- **An intraocular gas bubble is only good if *you know* what to do with it.**

10.7 Pneumatic Retinopexy

Pneumatic retinopexy is a term for the expanding-gas operation which was coined by Hilton and Grizzard in 1986. It differs from the expanding-gas operation, introduced by Kreissig in 1979 [17], only in that it is applied, instead, to uncomplicated detachments which are suitable for external buckling.

Therefore, if the expanding gases are used to tamponade *small tears which can be buckled*, the operation is called pneumatic retinopexy.

As you might recall (see Chapter 10.2.2, pp. 118–121) the use of the expanding gases for uncomplicated detachments with small breaks was introduced by Dominguez in 1985 [20]. In the following year, 1986, it was propagated by Hilton and Grizzard [21] and given some validity by a multicenter trial by Tornambe et al [39]. Tornambe's trial purpose was to demonstrate that the visual acuity is better with the gas operation than with external buckling (cerclages were used most of the time).

The indication for pneumatic retinopexy is limited to breaks in the superior $^2/_3$ of the retina. It is unsuitable for inferior breaks. Pneumatic retinopexy, which is an easy operation compared to scleral buckling, however, should be used with caution.

? Why?

▶ Because of the previously mentioned morbidity of an intraocular gas bubble.

? Are there special indications for pneumatic retinopexy?

▶ **Yes, there are some special indications, but they actually represent the indications for the previously discussed expanding–gas operation:**
- Detachments with retinal breaks at different latitude (sometimes applied in combination with the balloon buckle as part of the extended balloon-gas procedure and as demonstrated in Fig. 10.**39**).
- Detachments with posterior holes (see Fig. 10.**47**).

Both of these conditions are technically difficult to buckle.

? But are there uncomplicated detachments for which pneumatic retinopexy is indicated?

▶ **However, in our hands the balloon operation replaces pneumatic retinopexy in the treatment of most uncomplicated detachments.**

But, if you are not able to perform a balloon operation for a group of breaks at different latitude, and a scleral buckle would interfere with the function of a rectus or oblique muscle, pneumatic retinopexy might be indicated. Under these circumstances it is reasonable to risk the morbidity incurred by injecting gas into the vitreous. You will recall that intraocular gas provokes a loss of hyaluronic acid (up to 18.6%) and a destabilization of the vitreous structures [36], which can induce a cascade of biological responses that result in PVR and new breaks.

? What is so tempting about pneumatic retinopexy?

- The simplicity and brevity of the procedure, i.e.,
  For the doctor: It can be done in an office setting [21].
- The short time the patient has to invest for 1 treatment, i.e.,
  For the patient: Come and go.
- However, due to the higher morbidity in comparison to external buckling, more complications will develop, i.e.,
  For the patient: More reoperations
  (see Chapter 11, pp. 271–287).

10.8 Retrohyaloidal Gas Injection

10.8.1 Introduction

First, let us put things in perspective. When treating an uncomplicated detachment, an intraocular gas bubble with focal retinopexy harbors a greater morbidity than a local external buckle with focal retinopexy. However, when confronted with a complicated detachment, such as with a giant tear or posterior holes, and when weighing the morbidity of an intraocular gas against the increased morbidity of buckling in these detachments, the advantages of gases outweigh their morbidity. You will recall that these problem detachments actually represent the indication for the expanding-gas operation. The one drawback of the procedure are the secondary complications at the vitreoretinal interface.

To perform a vitrectomy prior to the gas injection was considered to remove *a priori* the vitreous, the source of complications.
But, as you have also already experienced, vitrectomy adds another degree of morbidity to the gas operation (see Chapter 13, pp. 299–308).

You will recall that an intravitreal gas bubble might reattach an already detached hyaloidal membrane, the cortical vitreous, to the surface of the retina, and that this might be the cause of proliferation and the development of starfolds (see Chapter 10.6.5.4, p. 247). Consequently, we looked for another alternative to reduce the complications which an intravitreal gas bubble might inflict at the vitreoretinal interface. To avoid or at least keep these developments to a minimum, we started to inject gas not into the vitreous, but behind the detached posterior hyaloidal membrane [51]. The thinking behind this approach is to avoid the other option, a vitrectomy. The intention is to reduce cellular reaction of the vitreous and PVR by the retrohyaloidal placement of gas.

**? This retrohyaloidal gas technique seemed feasible in a detachment with a large or a giant tear:
How should you proceed when you want to inject the gas bubble into the retrohyaloidal space?**

10.8.2 Technique

To inject *a priori* a large gas bubble, needed to tamponade a giant tear, you can use the basic balloon–gas procedure. Therefore, first place a balloon in the parabulbar space for decompression of the eye [42]. But in the detachment, depicted in Fig. 10.**54**, the extended balloon-gas procedure should be applied, because the parabulbar balloon could already tamponade the horseshoe tear at 7:30. About 2 hours later the gas is injected with a fluid–gas exchange under topical anesthesia to preserve the patient's light perception (see Chapter 10.5, pp. 159–166).

The gas is injected with the patient in a supine position. First, the posterior edge of the anterior flap of the tear is localized with the cryoprobe and the place marked on conjunctiva with cautery.

The sclera is perforated at the mark with a sharp 30-gauge needle (shortened to 6 mm by sliding a silicone tube over it). The distance from the limbus will lie between 8 and 10 mm.

- In contrast to the conventional technique of gas injection, the **tip of the needle**, being aimed towards the disk, is guided under ophthalmoscopic observation **beneath the anterior retinal flap** and beyond for an additional 1 to 1.5 mm.

The needle has to be kept in the same position during injection to prevent small gas bubbles from entering the subretinal space

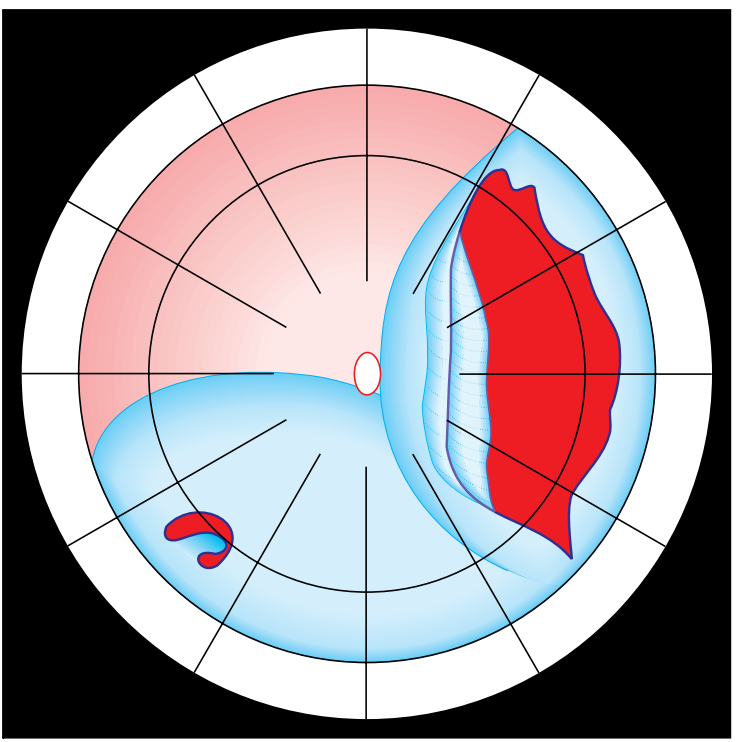


Fig. 10.**54** Detachment with a lateral giant tear (from 1:00 to 4:30) and an additional horseshoe tear at 7:30. It will be treated with a retrohyaloidal gas injection by applying the *extended* balloon-gas procedure.

(Fig. 10.**55**). The gas will rise immediately to the back of the lens, carrying the anterior flap and the cortical vitreous with it. Gas is injected until the patient reports a dimming of light perception. Light perception is restored within seconds by withdrawing some of the volume in the preplaced balloon. As you might recall when using the balloon–gas procedure between 0.5 ml and 0.8 ml of gas can be injected without prior victrectomy or drainage of subretinal fluid. Slit lamp examination now reveals the cortical vitreous against the back of the lens.

The patient is then rotated in the usual manner around the gas bubble, so that it would first compress and expand over the untorn retina. As the bubble expands, the patient is rotated, so that the

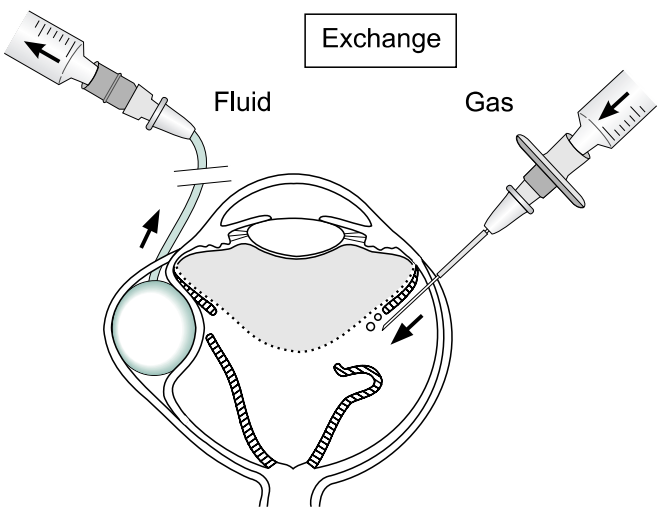


Fig. 10.**55** Diagram showing the *extended* balloon–gas procedure with a *retrohyaloidal gas injection* used for treating a giant tear detachment (Fig. 10.**54**). The inserted balloon is used at the same time as tamponade for the horseshoe tear at 7:30. The gas is injected into the retrohyaloidal space by perforating the globe with a sharp 30-gauge needle at the *posterior edge of the anterior flap* of the giant tear (8 to 10 mm from the limbus). The tip of the needle is guided under ophthalmoscopic observation, so that it appears beneath the flap, and is then moved forward in the same direction for an additional 1 to 1.5 mm. During the retrohyaloidal gas injection as much volume of the parabulbar balloon is withdrawn as to restore the patient's light perception.

gas bubble gradually approaches the giant tear, flattens it, and finally tamponades it. As already discussed, cryopexy is applied to the lateral edges of the tear and extended into the pars plana, the remaining edges are coagulated after reattachment. The patient should be placed in an optimal tamponade position.

- A postoperative slit lamp examination will reveal a thick layer of vitreous, discernible behind the lens. It is the proof that the gas bubble is retrohyaloidal.
- After absorption of the gas—and this differs from the findings after an intravitreal gas bubble—*circular vitreous structures are visible in the circumference of the far retinal periphery, i.e., they are located parallel to the ora serrata, on top of the untorn retina*.

In the beginning we were puzzled by these findings and interpreted them as being due to circular vitreous traction. However, after examination with biomicroscopy in combination with scleral depression and with dynamic ultrasonography,

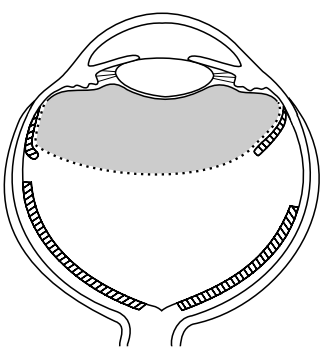


Fig. 10.**56** Diagram of the retina and vitreous after a *retrohyaloidal injection* of an expanding perfluorocarbon gas. The retina is reattached. The posterior hyaloidal membrane is still attached at the anterior flap of the giant tear, but it is detached across the posterior pole. The retina posterior to the equator is free of vitreous adhesions. Under biomicroscopy with scleral depression, the posterior hyaloidal membrane appears to be collapsed on top of the anterior retina, there discernible in concertina-like folds and in parallel arrangement towards the ora serrata. These findings are not depicted in the diagram.

- This peripheral phenomenon was recognized as collapsed posterior hyaloidal membrane in concertina-like folds on the anterior retina.
  The retina posterior to the equator appeared to be free of vitreous adhesions (Fig. 10.**56**).

10.8.3 Patients and Results

In a 1st study [51] 5 detachments with a giant tear ranging between 105° and 210° were treated with a gas injection into the retrohyaloidal space (Fig. 10.**57**).

In the 1 retina that failed to reattach, the tear was also torn radially, but folded over twice, and extended almost to the disk (Fig. 10.**58**). The rotation maneuver could not unfold this flap and so the gas was withdrawn. The patient did not agree to having another operation.

In the remaining 4 eyes with a giant tear, treated with a retrohyaloidal gas bubble, the retina was reattached, and during the follow-up of 6 years no apparent vitreous traction, starfold formations, or evidence of traction on the posterior edge of the tear were observed. Postoperative visual acuity of these patients ranged between 20/25 and 20/100 and remained unchanged during a 6-year follow-up.

10.8.4 Conclusion

- **The midvitreous injection of expanding gases promotes a cellular reaction in the vitreous, preretinal proliferation and posterior lip traction.**
  We concluded that this was the effect of the intravitreal gas bubble in combination with increased protein content, cellular infiltration of the vitreous, and mechanical compression of the lamellae of the vitreous cortex against the retina.
- Injecting the gas retrohyaloidally seemed to represent a rational change in the gas technique concerning the vitreous and the vitreoretinal interface. The number of patients treated in this way is too small to allow definite conclusions to be drawn.
- **In a 1st small series, i.e., in 4 out of 5 detachments with giant tears, treated by the retrohyaloidal gas technique without vit-**

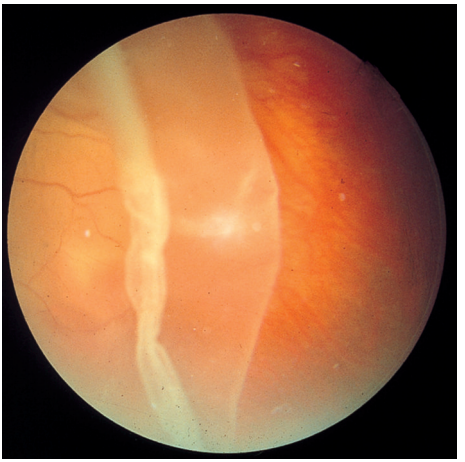
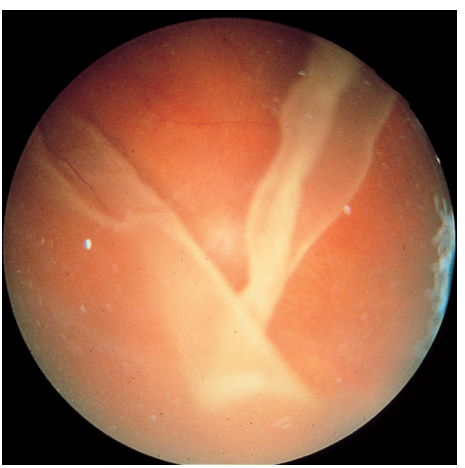


Fig. 10.**57** A detachment with a giant tear of 160° with the posterior flap being rolled over. By using the basic balloon-gas procedure, 0.9 ml of perfluorocarbon gas was injected into the *retrohyaloidal space*. The flap was unfolded by rotation with the small gas bubble of 0.9 ml of C_2F_6, which subsequently expanded, and retinopexy was applied as previously described. The retina was reattached. During a 6-year follow-up no redetachment or starfolds developed.



rectomy, the retina remained attached for a mean of 6 years. Postoperatively preretinal proliferation and starfold formation did not occur in the reattached retinas.

▶ Hyaloidal attachment in the far periphery persisted and was subsequently visible as thin and mobile vitreous structures on top of the anterior retina in its entire circumference. However, these structures did not exert traction since neither additional tearing nor redetachment of the retina had occurred during the long-term follow-up.

To verify a possible advantage of injecting the gas bubble into the retrohyaloidal space in the management of a giant tear detachment, further data needs to be collected. The results of subsequent detachments with a large or giant tear, treated with a retrohyaloidal gas bubble, appear to be encouraging.

10.9 Xenon Gas

10.9.1 Introduction

Intraocular gases came about to serve as an intraocular tamponade of a tear during the time it takes to form an adhesion of sufficient strength. As time went on it was the morbidity of the long-acting gases that led to the decision to restrict the use of gases in the treatment of tears not suitable for external buckling. However, the simplicity and brevity of the gas operation encouraged some to employ the gases as "pneumatic retinopexy" with focal retinopexy for uncomplicated detachments (see Chapter 10.7, pp. 256–258). But in uncomplicated detachments the accompanying morbidity of the gases resulted in less favorable results in comparison to external buckling (see Chapter 11, pp. 271–287).

In an attempt to reduce the vitreoretinal complications of the long-acting gases, a trial was carried out, injecting the gases into

◁ Fig. 10.**58** A detachment with a giant tear of 170° which, however, was torn additionally in radial direction almost to the disk and therefore was folded over twice. The gas was injected retrohyaloidally, but the twice folded over flap could not be unfolded by any rotation maneuver. The patient did not agree to another operation.

the retrohyaloidal space [51]. This would reduce cellular reaction of the vitreous[38] (see Chapter 10.8, pp. 258–264).

- **A gas bubble in the eye can have other uses besides serving as a long lasting tamponade.**
- **Gas can be used to replace lost intraocular volume:** The need can occur after an accidental perforation during dissection or when placing intrascleral sutures.

For these indications a temporary intraocular gas bubble with a shorter duration would be optimal.

? Why?

- — Because then the morbidity of a cellular response in the vitreous and secondary stimulation of preretinal proliferation can be avoided.
- — The morbid response of gas increases with the time the gas bubble remains within the eye.

Therefore, it seemed reasonable to use air for this indication or even a shorter duration gas, if longevity or expansion are not the specific requirements of the tamponade.

For this purpose Xenon gas was selected. Its rapid disappearance was predicted by **animal experiments** [52]:

After injection of Xenon gas into the rabbit eye, 88% disappeared in 3 hours. The gas was replaced by aqueous as rapidly as it went into solution, so that the hypotensive effect was small. The uveal response was less than with air or with a longer-lasting gas.

10.9.2 Clinical Study

In a clinical study [40] it was found that

- **In the human eye:**
  - **— The half-life of Xenon gas is 6 hours.**
  - **— After 16 hours about 90% of gas has disappeared.**

Ocular pressures taken within these 16 hours were between 8 mmHg and 14 mmHg. A protein flare (1+) and, rarely, a cell in

the vitreous were the maximum of inflammatory findings observed. The optic media were always clear for laser coagulation. By comparison an air bubble with a half-life of $1^1/_2$ to 3 days caused a 2+ protein flare and a significant cellular response in the vitreous.

? Is there a place for Xenon gas in retinal detachment surgery?

▶ **Yes,** there are 2 applications.

10.9.3 Applications

Due to the gas–fluid interface of the Xenon gas bubble it does not pass through a retinal break.

● **Xenon can be used:**
1. To restore intraocular pressure after drainage of subretinal fluid.
2. To press out inadvertent retinal folds on a circumferential buckle or so-called fishmouthing of a retinal tear which can cause leakage of the tear and failure of the reattachment operation.

10.9.4 Conclusion

The rapid replacement of Xenon by aqueous restores clear optic media within hours without the threat of vitreoretinal proliferation. Due to these optimal characteristics, Xenon gas has replaced the use of air.

● Consequently, as mentioned before (see Chapter 10.4, pp. 148–149):
A tank of Xenon gas should be available in the operating room for the retinal surgeon for the 2 above-listed situations.

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11 Balloon Buckle versus Pneumatic Retinopexy for Uncomplicated Retinal Detachments

11.1 Introduction

The balloon operation and pneumatic retinopexy represent minimal surgery. Both procedures are applied for uncomplicated detachments with breaks located within 1 clock hour. The operations are done with local anesthesia without drainage of subretinal fluid. Both provide a temporary tamponade during the time it takes for a cryopexy or laser application to form a retinal adhesion around the break.

In contrast to the balloon procedure, pneumatic retinopexy requires the patient to maintain a prescribed head position for 1 week.

? Why?

▶ To position the gas bubble into the area of the break or breaks to provide sufficient tamponade.

The difference between the 2 procedures is apparent: The balloon procedure is extraocular. The conjunctiva is incised for the insertion, but the balloon catheter is positioned external to the scleral wall in the area of the break. Pneumatic retinopexy is an intraocular procedure; the scleral wall is perforated and the gas is injected into the vitreous.

? The following questions arise:
1. **Which procedure has the better reattachment rate?**
2. **Which procedure has the least number of complications?**

▶ To answer these questions the surgical results of 1,000 uncomplicated detachments were analyzed, of which 500 were treated with one procedure and 500 with the other procedure.

In Tuebingen, having experienced the complications of intraocular gas, i.e., PVR and new breaks [1], we switched in 1979 from the gas to the balloon operation for uncomplicated detachments [2].

? When comparing the results of both procedures what are the differences?

11.2 Differences between Balloon Operation and Pneumatic Retinopexy

11.2.1 Application

The balloon operation can be used for superior and inferior breaks. But the gas operation is limited to detachments with breaks in the superior $^2/_3$ of the retina.

11.2.2 Surgical Technique

- With the balloon operation the catheter is inserted through a small incision in conjunctiva into the parabulbar space and the sclera is not perforated.
  The tamponade of the break or breaks is ab externo (Figs. 11.**1**, 11.**2**).
- With pneumatic retinopexy a needle is inserted through the scleral wall into the vitreous. There are intraoperative complications, i.e., gas under the retina, incarceration of retina and vitreous, hemorrhage and infection, when injecting the gas bubble.
  The tamponade of the break or breaks is ab interno (Fig. 11.**3**).

11.2.3 Postoperative Management

- With the **balloon** procedure the patient **does not have to maintain a special position** of the head postoperatively.
- With the **gas** operation the patient **has to maintain a necessary head position:**
  - Day and night.
  - For 1 week to provide the correct position of the gas bubble for a sufficient tamponade of the break or breaks during the time it takes to form a retinal adhesion.
  - To avoid closure of the anterior chamber angle by the gas bubble which, otherwise, would cause an abrupt rise in intraocular pressure.

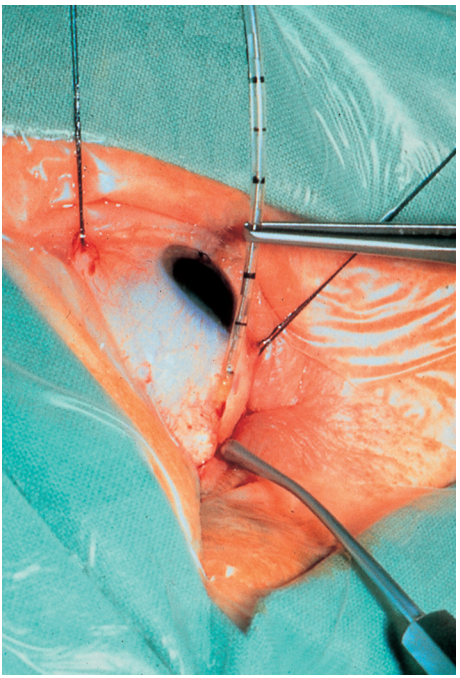

Fig. 11.1 **Balloon operation** implies an incision of 2 mm in conjunctiva and the balloon catheter with the stylette in place is inserted into the parabulbar space, positioned beneath the detached break and inflated with 0.7 ml of fluid after withdrawal of the stylette. There are no fixating sutures.

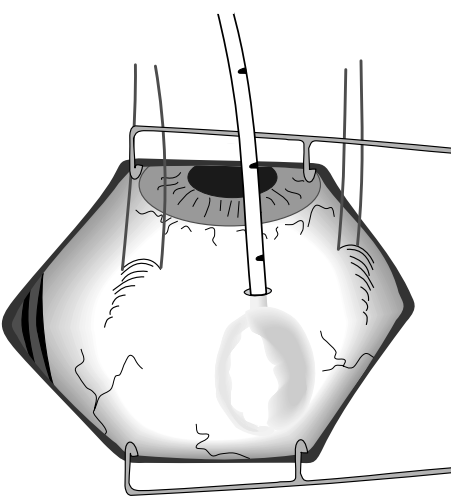

Fig. 11.2 Schematic drawing depicting the **inflated balloon after insertion** into Tenon's space and being positioned outside of the scleral wall in the area of the detached break. The parabulbar balloon represents a **tamponade of the break(s)** ***ab externo***.

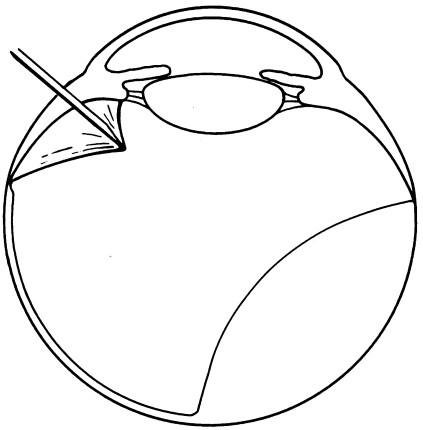

Fig. 11.3 **Pneumatic retinopexy** implies perforating the scleral wall with a sharp needle (5 mm in length, if necessary shortened by a piece of silicone tubing) to inject the gas bubble into the vitreous via the pars plana. Pneumatic retinopexy represents a **tamponade of the break(s) *ab interno***. The Figure also represents the risk one might encounter when injecting the gas into the eye. Prior to injection of the gas, one has to be certain that the tip of the needle has perforated a thin transparent membrane which might be adherent to the ciliary epithelium, otherwise the serious complication, "gas under the retina," will result.

As you see, there are already differences between the 2 procedures concerning their applicability, surgical technique and postoperative management.

? Are there also differences concerning the surgical results?

▶ To answer this question, the postoperative results of the 2 series were analyzed.

11.3 Clinical Studies

A total of 500 uncomplicated detachments (with 1 break or group of breaks within 1 clock hour) were operated upon with the parabul-

bar balloon by the author and the staff in Tuebingen; 500 comparable detachments were treated with pneumatic retinopexy by a group of experienced posterior segment surgeons in the United States and Europe [2].

11.3.1 Results

▶ **After balloon insertion**

The retina was reattached in 93%. After removal of the balloon, **redetachment occurred in 2%** (Table 11.**1**). After 1 reoperation reattachment was achieved in 98% and after a 2nd reoperation (n = 4 of 500) in 99%. But the following should be borne in mind:

- **After 1 balloon operation** and removal of the balloon **the retina remained attached in *91%*.**

The final result of 99% retinal reattachment was obtained after **1 to 2 reoperations.**

▶ **After pneumatic retinopexy [2–12]**

The retina was reattached in 91%, however—and this is the crucial difference—after absorption of the gas
redetachment developed in 11% (versus 2%) (Table 11.**2**). Thus:

- **After gas absorption, the retina remained attached in *only 80%*.**

A final reattachment of 99% with pneumatic retinopexy was obtained after **1 to 3 reoperations.**

? What was the cause of the different rate of redetachments?

▶ The difference in morbidity between the 2 procedures.
Let me explain this to you.

Table 11.**1** Anatomical results with parabulbar balloon in the treatment of 500 uncomplicated detachments

Surgeons	Detachments (n)	Initially reattached with balloon	Reattached after balloon removal	Reattached after 1 reoperation	Reattached after 2 reoperations (n = 4)
Kreissig + staff	500	466 (93%)	454 (91%)	490 (98%)	493 (99%)

Table 11.**2** Anatomical results with pneumatic retinopexy in the treatment of 500 uncomplicated detachments

Surgeons	Detachments (n)	Initially reattached with gas	Reattached after gas absorbed	Reattached after 1–3 reoperations
Hilton and Grizzard [3]	20	20	18	20
Dominguez et al [4]	43	43	40	42
Effentèrre et al [5]	60	54	51	59
Gnad et al [6]	27	25	24	27
Hilton et al [7]	100	91	84	98
Poliner et al [8]	13	12	9	13
Bovey et al [9]	27	19	18	27
Chen et al [10]	51	40	32	n/a
McAllister et al [11]	56	48	40	56
Tornambe et al [12]	103	102	82	102
Total	500	454 (91%)	398 (80%)	444 (99%)*

n/a: not available; * of 449 detachments.

11.3.2 Complications

The main complication after the balloon operation is extraocular (Table 11.**3**): A superficial corneal erosion in 5%. It can be avoided, if the balloon catheter is directed away from the cornea at the end of the operation.

*After balloon operation intraocular complications were **0.8%.***

For comparison, the complications after pneumatic retinopexy are shown (Table 11.**4**):

Table 11.**3** Complications of 500 balloon operations [2]

Complication	**n**
Corneal erosion	25 (5%)
Iridocyclitis	2
Macular pucker	1 } 4
Choroidal effusion → PVR	1
Intraocular complications	4 **(0.8%)**

Table 11.**4** Complications of 103 pneumatic retinopexies [12]

Complication	**n**
Vitreous incarceration Subretinal gas Anterior subhyaloidal gas Vitreous hemorrhage Hyphema Macular hole Endophthalmitis Cataract Uveitis Glaucoma	14
Intraocular complications	14 **(13.6%)**

After gas intraocular complications were ***13.6%****, i.e., 15 times more frequent than after the balloon procedure.*

And here are the more serious complications concerning the retina:

- ***After the balloon operation*** (Table 11.**5**) new breaks developed in 1.4% and PVR in 0.2%.
- ***After pneumatic retinopexy*** (Table 11.**6**) new breaks occurred in 15% (between 4% and 30%), and PVR in 4% (between 2% and 10%).

Table 11.5 Complications after 500 balloon operations for uncomplicated detachments

Surgeons	Detachments (n)	New/missed breaks	PVR
Kreissig + staff	500	7 (1.4%)	1 (0.2%)

Table 11.6 Complications after 500 pneumatic retinopexies for uncomplicated detachments

Surgeons	Detachments (n)	New/missed breaks	PVR
Hilton and Grizzard [3]	20	1	1
Dominguez et al [4]	43	2	1
Effentèrre et al [5]	60	7	1
Gnad et al [6]	27	1	0
Hilton et al [7]	100	7	3
Poliner et al [8]	13	2	1
Bovey et al [9]	27	8	2
Chen et al [10]	51	11	5
McAllister et al [11]	56	11	1
Tornambe et al [12]	103	24	3
Total	500	74 (15%)	18 (4%)

- ***After pneumatic retinopexy:***
  - **Secondary breaks developed 10 times and PVR 20 times more often** than after the balloon procedure.
  - **The difference in complications between the 2 procedures is highly significant** (chi square = 13.7; P = 0.0002).

- **Here is the answer to the questions raised in the beginning:**
  The difference in morbidity between the 2 procedures is the basis of the **higher rate of redetachments and reoperations after pneumatic retinopexy.**

11.4 Conclusion

Only upon analyzing the complications did the 2 compared procedures differ most. The intraocular complications with the balloon procedure are less than 1%; with pneumatic retinopexy they are 15 times more frequent. The less frequent ones are "gas under the retina" [13] (see Fig. 11.**3**) and endophthalmitis. More frequent are PVR and secondary breaks. The last 2 can be considered as a consequence of the break down of the blood aqueous barrier [14]. This is a well-documented effect of an intraocular gas bubble [15].

As you might recall: As result of the break down of the blood aqueous barrier there will be protein and cells in the vitreous which provoke proliferation on the retinal surface.

- **Therefore, it is not surprising that:**
  - **Secondary breaks** occur between 4% and 30% (**mean 15%**) **in the gas-treated** group (or, as reported by others, between 6% and 22% [16–19]). On the contrary, secondary breaks after the
    - ***balloon operation occurred in 1.4%***.
      This is within the range of the natural evolution of a retinal detachment whose vitreous has not been provoked.
  - But most striking is the postoperative development of **PVR in the gas-treated eyes.** This is
    - **20 times more *than experienced with the balloon operation*** [2].
  - **Even more indicting for pneumatic retinopexy as primary operation is:** Up to
    - **16% of gas-treated detachments** subsequently **required a vitrectomy** for reattachment to be achieved, whereas only
    - ***0.2% of eyes treated with the balloon*** eventually **required a vitrectomy.**

Tornambe [20] has also observed these complications and after an analysis of the long-term results of 302 pneumatic retinopexies which he performed,

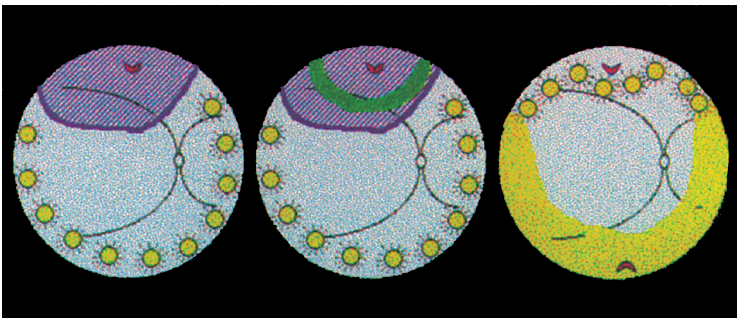

Fig. 11.**4** 1-quadrant detachment with a hole at 12 o'clock, treated by **pneumatic retinopexy with 360° of retinopexy** (Figure from Tornambe [20]). *Left: 1st step of treatment:* Scatter peripheral photocoagulation is applied to the attached retina between the insertion of the vitreous base and ora serrata. *Middle: 2nd step of treatment:* A gas bubble is injected into the vitreous and the patient has to be positioned. *Right: 3rd step of treatment:* Photocoagulation is completed for a 360° retinopexy when the superior retina is reattached postoperatively. If a new break should develop subsequently within the laser treated area (e.g., a tear at 6 o'clock), retinal detachment should not occur due to the existing retinal scars.

- **He suggested the following 2 changes:**
  - A more restricted selection of patients for pneumatic retinopexy.
  - An addition of 360° of retinopexy to the procedure, supplementary to the focal retinopexy around the break.

  However, with this modification (by adding a 360° retinopexy), pneumatic retinopexy has lost its simplicity and is no longer a brief procedure.

Here are some statements made by Tornambe in his recent monograph on pneumatic retinopexy [20], for example: "Most favorable cases include phakic eyes with a less extensive detachment secondary to a superior retinal break less than 1 clock hour in size and no PVR" (Fig. 11.**4**).

- Therefore, Tornambe postulated:
  A successful pneumatic procedure should include peripheral retinopexy placed between the insertion of the vitreous base and ora serrata for *360°*.

Under these conditions, the expected "single-operation" success rate approaches 97%.

- **However, the success of this "single-" operation with pneumatic retinopexy is:**
  - Limited to a favorable subgroup of detachments, i.e., phakic eyes with a 1-quadrant detachment with 1 break in the superior $^2/_3$ of the fundus.
  - **This procedure actually consists of *3 steps*:**
    - Coagulation to the entire attached retinal periphery.
    - Intraocular gas injection.
    - Laser coagulation to the rest of the retinal periphery after reattachment of the superior retina to obtain the 360° retinopexy (Fig. 11.**4**).

- **Now we take the same uncomplicated detachment as in** Fig. 11.**4, but this time we treat it by the balloon operation.**
  - **This procedure consists of *1 step:***
    - Cryopexy with a parabulbar balloon in the area of the break (Fig. 11.**5**).
      And this is all that has to be done.

In the following text are more restrictions of pneumatic retinopexy, as defined by Tornambe in March 1998 at the 1st Vitreoretinal Symposium in Frankfurt: "If you do not add this prophylactic 360° retinopexy, you have to subtract 10% from the success rate for each additional risk factors, such as: Multiple breaks, a more extensive detachment, or pseudophakia. If only focal retinopexy is applied, then you have to subtract another 10% to 20%."

Let us recall the restricted selection of uncomplicated detachments suitable for pneumatic retinopexy and the additional need for an extension of retinopexy to 360° to achieve sustained reattachment.

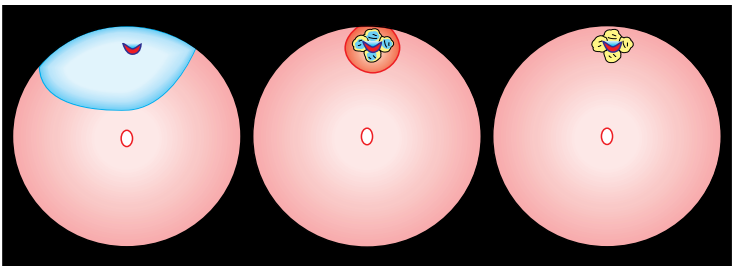

Fig. 11.**5** The same 1-quadrant detachment as in Fig. 11.**4** with a hole at 12 o'clock, but this time treated instead by **a parabulbar balloon with retinopexy, limited to the area of the hole**. *Left:* Detachment prior to treatment. *Middle: The treatment:* Cryopexy around the hole at 12 o'clock with placement of a parabulbar balloon beneath it. Postoperatively the patient does not have to be positioned. *Right:* After treatment. The balloon was withdrawn after 1 week; no supplementary treatment had to be added.

At the same time you might recall the larger spectrum of indications and the still favorable results obtained by the temporary balloon buckle representing a small procedure, as discussed earlier (see Chapters 9.6 and 9.7, pp. 25–104).

Consequently, you might ask:

? Does the change in pneumatic retinopexy from applying a focal to a 360° retinopexy imply a fortunate change?

- Reflect for a moment over the pros and cons.
- **In fact,** the modified pneumatic retinopexy no longer represents this often cited minimal surgery, but instead—to obtain better results—the procedure has to be enlarged by extensive and **prophylactic laser coagulations extending over 360°.**

? Does an earlier development in retinal detachment surgery come to mind?

- The treatment of a retinal detachment by an extensive **prophylactic buckle**, i.e., by a ***cerclage***.

– This time it is the treatment by **pneumatic retinopexy,** combined with extensive **prophylactic retinopexy**,
i.e., by a ***"virtual cerclage" of coagulations.***

Therefore, if you intend treating an uncomplicated detachment **with minimal surgery and with a true single-operation success rate of more than 90%, then there is actually no choice.**

As you will recall, it is better not to enter the vitreous, but instead to limit your surgery to the extraocular space within the area of the break, i.e., to perform a **balloon operation.**

? But why has the balloon operation not yet acquired the popularity pneumatic retinopexy did?

▶ As already pointed out, the balloon operation
– though an **easy operation for the eye**
– is more **difficult for the surgeon.**

? Why?

▶ **It requires:**
– Skillful indirect ophthalmoscopy and not having overlooked a break.
– Precise intraoperative localization of the detached break on mobile conjunctiva.
– Correct evaluation of the detached break above a parabulbar balloon, having not yet reached its final indentation at the time of surgery.

Consequently, the following premise should be fulfilled when starting with the balloon procedure.

● **The balloon operation should be done by a retinal surgeon:**
– **Skilled in indirect ophthalmoscopy**
– **Providing sufficient experience in the non-drainage technique.**

11.5 Summary

▶ When treating a retinal detachment with a break or group of breaks within 1 clock hour the external temporary balloon buckle has proved to be a less morbid procedure than pneumatic retinopexy. The results of 500 uncomplicated detachments, treated by experts using either method, imply without doubt that:

● **An external buckle is better than an intraocular gas bubble.**

Because even after failure with the balloon operation, reoperation with another procedure will not be delayed, nor will its prognosis be jeopardized.

▶ This is not the situation with pneumatic retinopexy. On the contrary, eyes that fail to remain attached after pneumatic retinopexy are disadvantaged.

? **Why?**

▶ **Because after pneumatic retinopexy the rate of PVR,**
- still representing at present the main cause for final failure,
- **will be 20 times more frequent** than would be expected after a parabulbar balloon.

Therefore, at this point we think that, given a vitreous that is already active enough to provoke a retinal detachment, it seems unwise to provoke it further with an intraocular gas bubble.

? **Is there still a place for pneumatic retinopexy with focal retinopexy as a primary procedure?**

▶ Almost none. Let me explain this to you.

▶ A morbidity of 4% to 10% PVR [2,16–19] may be acceptable in detachments in which the morbidity of scleral buckling would be as great. This could be perhaps the case, for example, in a

detachment with a large and irregular tear at 12 o'clock, which would require a large radial or circumferential buckle that would compromise the function of the superior rectus muscle.

▶ **However, this indication for pneumatic retinopexy would be valid only *if* the extent of the tear *exceeded 6 mm.***

? Why?

▶ Because **tears as large as 6 mm** can still be treated by an extraocular temporary balloon buckle.

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12 Limits of External Buckling in Treating Complicated Retinal Detachments

12.1 Background

In this Chapter the limits of segmental buckling will be discussed and the indication for an alternative operation, either the gas operation or vitrectomy with gas, will be presented.

12.2 Limits of External Buckling

12.2.1 Due to Location or Size of Tear

▶ Posterior holes

These holes are limited to a circumscribed area at the posterior pole and comprise 1% to maximal 2% of retinal breaks in a consecutive series of detachments (see Chapter 10.6.3, pp. 221–232). Buckling of posteriorly located holes harbors a greater morbidity than tamponading them by an intraocular gas bubble.

In this situation a gas tamponade may be the method of choice; a primary vitrectomy is not needed.

▶ Group of breaks at different latitude

Breaks at different latitude can be treated with external buckling. However, the issue of its limits can arise when one buckle is interfering with the other or the breaks at different latitude exceed the extent of a scleral pouch (see Part 1, Chapters 8.8.2–8.8.6, pp. 181–190). Therefore, the buckles have to be placed precisely and should not be larger than required to reduce the risk of buckles interfering with each other or the morbidity of large or very posterior buckles. As a consequence, skillful indirect ophthalmoscopy and precise localization of the detached breaks are mandatory.

The extraocular procedure has a minimum of complications [1].

The alternative procedures, such as an intraocular gas bubble (pneumatic retinopexy) or a gas bubble combined with prior vitrectomy, have a higher morbidity. As will be discussed in the next Chapter (see Chapter 13, pp. 299–308) there is a greater risk of PVR, i.e., 4% [2] to 6.1% after gas or 11.5% after vitrectomy, and a greater need for reoperations, i.e., 19% [2] to 26% after gas or 24.5% after vitrectomy.

▶ Tears larger than 70°

For tears with an extent between 70° and 180°, the expanding-gas operation without prior vitrectomy is worth trying because the results are favorable (see Chapter 10.6.1, pp. 167–212).

When treating tears larger than 180°, or in the hands of some surgeons tears larger than 90°, the gas operation is combined with a prior vitrectomy. If in addition a rolled-over posterior flap of the giant tear has to be unfolded, the use of heavy perfluorocarbon liquids [3] as a mechanical tool is needed, although the manipulation with a small gas bubble may suffice [4].

12.2.2 Due to Vitreous Traction

▶ Excessive local traction on a tear

This represents a detachment in which the tear was either closed primarily by a segmental buckle, but subsequently redetached—with no possibility of reattachment by the addition of a cerclage—or it was not closed off primarily by an external buckle due to excessive traction upon it. A gas operation will not help, on the contrary it may increase proliferative vitreoretinopathy.

With vitrectomy the localized excessive traction can be removed. Admittedly, the finding of an excessive traction is rare; it was present in less than 2% in a series of 752 rhegmatogenous detachments [5].

▶ Extensive circular vitreous traction on the retina

Prior to the advent of vitrectomy, the presence of extensive circular vitreous traction was the indication for a cerclage. If the vitreous traction was not excessive, the retina might have been reattached with a constriction of the globe. However, the constriction should be not more than 15% because more constriction carries with it a marginal morbidity in terms of circulatory disturbances, which can jeopardize subsequent visual function (see Part 1, Chapter 8.11, pp. 195–204).

In a primary detachment vitreous traction is usually mild. When present, it tends to be limited to 1 or 2 quadrants, manifested by starfolds. As discussed earlier, in these detachments it is worthwhile to try buckling first (see Part 1, Chapter 8.18.2–8.18.5, pp. 257–277). As you will recall, in a series of 107 consecutive detachments,

there were 16 eyes with PVR grade C1 or C2 [6]. In another series of 72 selected detachments with moderate PVR (grade B in 22 eyes and grade C1 or C2 in 50 eyes), recruited out of 695 consecutive detachments, the retina reattached in 79% after buckling the tear, and in 86% after a 2nd buckling procedure [7].

? What does this imply?

▶ Even if vitreous traction is in 2 quadrants, manifested by ***starfolds, localized buckling might suffice:***
- **In 8 out of 10 detachments with PVR grade B, C1, or C2, the retina was reattached by an extraocular approach with a minimum of morbidity.**
- ***And a vitrectomy was not needed.***

12.2.3 Due to Opacities within the Optic Media

▶ **Vitreous hemorrhage**

Confronted with a vitreous hemorrhage of rhegmatogenous origin, a clearing of the optic media might result after double patching and elevating the patient's head (see Part 1, Chapter 3, pp. 28–40). Even if the resulting view of the retina is not optimal, with skillful indirect ophthalmoscopy and depression of the anterior retina, either the breaks can be detected or the borders of the detachment determined.

? Why is this possible in the presence of a vitreous hemorrhage?

▶ Because the blood is retrohyaloidally early after a rhegmatogenous hemorrhage and the anterior retina will not be obscured because the vitreous base is attached. Therefore, the view to the anterior retina is accessible with indirect ophthalmoscopy and simultaneous depression (see Part 1, Chapter 3.2, page 29, Fig. 3.**1**).

Having determined the borders of the detachment by viewing the anterior retina, you might be able to detect the break in the area of probability (see Part 1, Chapter 2.2, pp. 13–18) prior, or at least

during surgery. If you have still not found the break, then you might resort to buckling the area of maximal probability and so maintain a limited extraocular approach.

A rhegmatogenous vitreous hemorrhage infrequently represents the indication for a vitrectomy to clear the optic media, if the possibilities of binocular occlusion with elevation of the patient's head and indirect ophthalmoscopy with depression of the anterior retina are skillfully employed.

Cataract

Cataracts are seldom so dense as to prevent an examination of the anterior retina with indirect ophthalmoscopy and depression. The borders of the detachment can usually be defined anteriorly.

? Which advantage is there in being able to determine the borders of a detachment behind a cataract?

To assign this detachment to the correct type of detachments and thus to be able to predict the location of the retinal break 95% of the time.

Prospective segmental buckling in the predicted area represents an alternative (see Part 1, Chapter 4.4.4, pp. 48–53) which succeeds in 76% [8] and has few complications [6].

Intraocular lens with a narrow pupil and secondary cataract

The retinal surgeon is increasingly confronted with these findings. They represent a challenge for skillful diagnostics. To cope with this problem and still be able to apply a procedure with minimal morbidity and obtain optimal long-term results (see Part 1, Chapters 8.15 and 8.16, pp. 231–250), the following are necessary: Skillful indirect ophthalmoscopy and the use of the indirect wide-field contact lenses [9] and the new one, designed for small pupils by Lincoff (see Part 1, Chapter 4.3, page 46, Fig. 4.**2**).

In this situation the limits of extraocular buckling are not determined by the size or location of the break, nor the vitreous trac-

tion, but by the quality of the anterior optic media and the expertise of the surgeon in skillful indirect diagnostics. The study to detect the break or breaks can be time consuming and laborious. It can be avoided by resorting to

A vitrectomy, which is combined with a preceding anterior segment surgery:

1. To remove the opacities in the pupil.
2. To enlarge the iris aperture.
3. To remove the anterior and posterior vitreous.

- **However, the difference between an intraocular and extraocular approach in treating these pseudophakic detachments will again be *the morbidity:***
  - **The rate of PVR,**
  - **New breaks, and**
  - **Reoperations*(see Chapter 13, pp. 299–308).***

12.3 Conclusion

More than 90% of rhegmatogenous detachments can be treated by extraocular minimal buckling alone:

- **In the 1st category of difficult detachments** the limits of this minimal procedure are exceeded when the tears are posterior (in about 1%), or multiple at different latitude (in 2% to 3%), or with a circumferential extent greater than 70° (in 1% to 2%). A tamponade with an expanding gas bubble and without drainage represents the next level of a minimal approach for these conditions, but implying already an intraocular injection. In this 1st category a gas tamponade will suffice.
  An additional vitrectomy will only be needed for the rare situation of a giant tear 180° or larger in extent or, in some hands, if larger than 90°.
- **In the 2nd category of difficult detachments,** those with excessive local vitreous traction that caused the redetachment of a buckled horseshoe tear or those with a proliferative vitreoretinopathy in more than 2 quadrants, a primary vitrectomy may be indicated. However, it is not indicated per se if the starfolds are more than 1 clock hour apart from the tear to be buckled. Also, in

these difficult detachments buckling first is worthwhile [7] (see Part 1, Chapters 8.18.2–8.18.5 pp. 257–277).
However, if one decides upon a vitrectomy, it has to be combined with a meticulous removal of proliferative preretinal membranes and the anterior vitreous.

? **Why?**

▶ Because the additional gas tamponade, combined with the vitrectomy, will provoke in particular anterior vitreoretinal proliferation if residual vitreous is present.

▶ **In the 3rd category of difficult detachments,** the pseudophakic detachment, the problem is in the opacities of the optic media after anterior segment surgery that seem to preclude the application of minimal external buckling. However, the limits of external buckling in this 3rd category are in a gray zone.
The indication for a vitrectomy, combined with a preceding anterior segment surgery, does not depend on the size of the tear or vitreoretinal proliferation, but on the expertise of the surgeon in indirect diagnostics in the presence of optical interferences.

– **Instead of trying to overcome these problems in the optic media by a time consuming and laborious study in the days prior to surgery to detect the break or breaks and thus still to be able to apply an *extraocular* minimal buckling procedure**, the problem can be solved
more conveniently on the day of surgery in the operating room:
  - By vitrectomy with the use of assistance and high-technology instruments.

– **In addition, this *intraocular* approach implies for the surgeon the following change:**
  - To remove first the opacities with intraocular surgery, after that
  - To view the retina with intraocular fiberoptics to search for the break and
  - To reattach the retina already on the operating table by injecting **an intraocular tamponade of gas or silicone oil.**

Now view these facts in perspective:

? But where does the actual problem in such pseudophakic detachments lie?

▶ Not in the retina, but in the **anterior segment** presenting optical interferences after cataract surgery with an intraocular lens.

First, it should be remembered that modern cataract surgery with implantation of an intraocular lens has brought about a great change and improvement in the quality of life of these patients. However, pseudophakia might cause difficulties if a retinal detachment develops, in particular, if the lens has a small diameter. Consequently, a change in cataract surgery might come about in the future to reduce these optical problems.

Let's speculate: Perhaps new developments in refractive surgery, e.g., of the cornea, or other inventions, might even circumvent *a priori* the problems we might be confronted with after the present type of cataract operation.

? But what might be needed in the *short term?*

▶
- **Improve your ability in indirect retinal diagnostics** to detect and localize the break in pseudophakic detachments in spite of problems in the optic media.
- **Learn the "Art of minimal extraocular buckling"** to become competent to apply it in spite of optical problems present in these eyes.

This knowledge should still be acquired for today's patients and might be transferred to upcoming retinal surgeons.

? Why?

▶ Because—after the great efforts of several generations of inventive and devoted retinal surgeons—the treatment of retinal detachment might have already reached its optimum in its present state, i.e., in the **"Art of minimal extraocular surgery".**

? But what might be needed in the *long term?*

- An alternative to improve today's treatment of pseudophakic detachments:
  Rather than extending the indication for vitrectomy to these eyes—that is, to first perform an anterior segment surgery, so as to remove the opacities in the optic media, and subsequently to perform the detachment operation—a different cataract surgery could be considered. This might be another method to compensate for the lost refraction, or further modifications of the present cataract technique.
- The latter could, e.g., imply a cataract surgery:
  1. That leaves fewer keratocytes in the periphery making for less risk of subsequent opacification of the lens capsule.
  2. That implants a larger intraocular lens.
  3. That maintains a mobile and fully dilatable pupil.
- **All of this would provide more favorable conditions for the pseudophakic patient with a detachment.**

? Why?

- **Because thereafter the view to the retinal periphery will no longer be precluded. As a result,**
- **The time-tested minimal extraocular surgery:**
  1. With a minimum of morbidity, secondary complications, reoperations, and with optimal long-term visual results,
  2. **Can still remain the treatment of choice for the patient with a detachment after a cataract operation.**

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13 Pneumatic Retinopexy versus Vitrectomy as Primary Procedure for Retinal Detachments

13.1 Background

Both procedures represent an intraocular approach. The rationale for both to be used as primary procedure for uncomplicated detachments is the following:

? If both are good for complicated detachments, i.e., pneumatic retinopexy, or more correctly termed expanding-gas operation [1], for a giant tear and vitrectomy for a detachment with PVR, why not try them for detachments with small tears and detachments without PVR?

▶ The obvious answer is that the morbidity of the 2 procedures is excessive when compared to the morbidity of an extraocular minimal buckling procedure.

An analysis of pneumatic retinopexy versus a temporary external buckle for uncomplicated detachments has already been done (see Chapter 11, pp. 271–287). It was found that because intraocular gas causes a break down of the blood aqueous barrier, PVR will occur 20 times more frequently and secondary breaks 10 times more frequently than after a balloon buckle [2]. As a consequence reoperations will be more frequent than after external buckling. To reduce the higher redetachment rate of pneumatic retinopexy, Tornambe [3] suggested adding 360° of coagulation to the periphery of the retina, thus providing a virtual cerclage consisting of circular coagulations. However, with this change pneumatic retinopexy has lost its appealing simplicity.

● **Additional reasons were suggested for using vitrectomy as a primary procedure:**
- The traction on the operculum of the tear can be severed with the vitrector.
- Removing the vitreous might eliminate vitreoretinal proliferation, a main cause for failure with the gas operation.

These reasons alone appear to represent an advantage of vitrectomy over the gas operation. However, let us recall what we know already

about vitreous traction on a horseshoe tear. Rarely does it represent a problem for reattaching the retina with an external buckle.

? Which information confirms these statements?

- Among 500 detachments treated by a temporary balloon buckle, 70% were caused by horseshoe tears, and after removal of the balloon, only 2% of the tears redetached [2].
- Thus, removing the vitreous attachment to the operculum is rarely required to reattach a retina.

Most of the time, traction on the operculum can be overcome in the long-run by anterior coagulation alone, as demonstrated by the long-term results with the temporary balloon buckle which is removed after 1 week.

? Or how can it be defined in another way?

- **With segmental buckling we relieve traction on the tear ab externo** by placing a buckle underneath it and leaving it there for at least the duration of retinal scarring.
- **But with vitrectomy we relieve traction on the tear ab interno** by cutting the operculum off and adding an internal gas tamponade which will be there during retinal scarring.

? Of course you can select a vitrectomy for retinal reattachment. But is it any better than just performing the gas operation alone?

Before presenting the data on this topic, let me discuss with you another issue.

? If an acute horseshoe tear is sent to you, would you still consider relieving traction by vitrectomy or even by an external buckle *before* a detachment occurs?

? Or would you rather seal it simply by laser or cryopexy?

▶ There is little doubt that coagulation alone is the proper treatment.

Years ago as prophylaxis, attached horseshoe tears were even buckled, sometimes with a cerclage [4] or by a radial buckle with a cerclage [5]. However, today nobody would consider a prophylactic buckle even though up to 2% of horseshoe tears may detach after prophylactic coagulation.

● – **It seems unreasonable to buckle 98 eyes to save 2 eyes from a buckle operation at a later date.**
– Consequently, performing a primary vitrectomy to remove the vitreous attachment to the tear does not seem reasonable either.

Here is another question that might arise in relation to vitrectomy:

? Does primary vitrectomy not, after all, reduce the rate of PVR or reoperations when compared to pneumatic retinopexy?

▶ – To begin with, you should take into account the fact that when performing a vitrectomy in addition:
  - **To remove the traction on the tear**
  - **To remove the *posterior and the anterior vitreous***
  - Otherwise you are likely to get **anterior loop proliferations** causing even larger amounts of postoperative PVR and reoperations.

– **Such a vitrectomy would be then an extensive intraocular procedure with a significantly higher rate of complications.**

? But which complications have to be expected when performing such an *extensive vitrectomy*?

▶ — Iatrogenic tears
— Anterior PVR
— Cataract
— Glaucoma

? However, what will finally reattach the retina after such an extensive vitrectomy?

▶ **An intraocular gas tamponade of 1 week's duration** which is in fact a pneumatic retinopexy (or an expanding–gas operation) augmented by the preceding vitrectomy.

Therefore, the question should rather be:

? Does adding a vitrectomy to a gas operation provide a significant advantage and improvement over the results obtained by pneumatic retinopexy alone?

▶ To answer this question the results of the 2 procedures will be compared.

13.2 Results

In Tables 13.**1** and 13.**2** the results of pneumatic retinopexy [6–17] and primary vitrectomy [18–27] are compared. The Tables represent a collection of more recent reports on this subject available in the literature. The reports do not represent prospective studies, nor a homogenous cohort of detachments. The detachments selected for pneumatic retinopexy (see Chapter 10.7, pp. 256–258) had 1 break or multiple breaks in the anterior and posterior retina located in the upper $^2/_3$ of the fundus; there were phakic, aphakic, or pseudophakic eyes.

The indication for primary vitrectomy, as stated by the various authors [18–27], included: PVR stages B and C, vitreous

Table 13.1 **Pneumatic retinopexy** as treatment for retinal detachments: Rate of reoperation and PVR

Author	Year	Detachment	Reoperation	PVR
Algvere [6]	1988	58	21	8
Lowe [7]	1988	55	10	3
Tornambe [8]	1989	103	28	3
Termote [9]	1989	20	4	1
Skoog [10]	1989	50	9	n/a
Lemmen [11]	1989	54	27	3
Berrod [12]	1990	56	19	9
Algvere [13]	1992	51	7	2
Bochow [14]	1992	17	5	2
Sebag [15]	1993	45	6	2
Gunduz [16]	1994	30	3	1
Boeker [17]	1994	133	36	7
Total		672	175 (26.04%)	41* (6.10%)*

n/a: not available; * of 622 cases.

hemorrhage, no break found, large breaks, multiple breaks, posterior breaks, and pseudophakia.

However, a common denominator among the detachments selected for pneumatic retinopexy or primary vitrectomy was that:
The detachments selected for both procedures, with few exceptions, were regarded by the authors as also suitable for external buckling.

? But are there discernible differences when analyzing the results after pneumatic retinopexy and primary vitrectomy?

- **The failure rate due to PVR is with:**
  - Pneumatic retinopexy 6.1%
  - Vitrectomy with gas 11.5%
- **The rate of reoperation with:**
  - Pneumatic retinopexy 26%
  - Vitrectomy with gas 24.5%

Table 13.2 **Primary vitrectomy** as treatment for retinal detachments: Rate of reoperation and PVR

Author	Year	Detachment	Reoperation	PVR
Escoffery [18]	1985	29	6	2
Wong [19]	1987	47	19	n/a
Rosen [20]	1989	78	14	9
Hakin [21]	1993	124	44	25
Gartry [22]	1993	114	30	10
Hoeing [23]	1995	32	7	6
Bartz-Schmidt [24]	1996	33	2	1
Heimann [25]	1997	53	19	9
El-Asrar [26]	1997	22	0	1
Oshima [27]	1998	63	5	0
Total		595	146 (24.5%)	63* (11.5%)*

n/a: not available; * of 548 cases.

- **— The most unexpected finding is that the results of both procedures, i.e., *PVR and reoperation,* are strikingly similar.**
- — A statistical analysis revealed no difference in the results of pneumatic retinopexy and vitrectomy when applied as a primary procedure for uncomplicated retinal detachments.

Consequently, since there is no relevant difference between pneumatic retinopexy and vitrectomy with gas we might better compare the results of these 2 procedures with those of segmental buckling (see Part 1, Chapter 8.15.3 pp. 236–242) and the balloon procedure, which, however, was already discussed in Chapter 11, pp. 271–287.

- **Yet a difference not to be overlooked, however, is that:**
- **— The reoperation rate**
  After extraocular minimal buckling is < 10%, i.e., between 4.7% (segmental buckling) and 8.4% (balloon),
  but not 24.5% and 26% as after the 2 intraocular operations.
- **— The incidence of PVR** in primary detachments
  After extraocular minimal buckling is between 0.2% (balloon) and 3.7% (segmental buckling),
  but not 6.1% and 11.5%, as after the 2 intraocular procedures.

13.3 Conclusion

- Either procedure, pneumatic retinopexy or vitrectomy, can reattach an uncomplicated detachment without doubt.
- After several reoperations the final result for this category of detachments will approach the 99% reattachment rate that can also be achieved with extraocular minimal buckling [2].
- However, morbidity is the critical factor. External minimal buckling without drainage, applied as a temporary balloon buckle [2] for breaks within 1 clock hour or as segmental buckles for multiple breaks [28], has fewer complications and less PVR (0.2% or 3.7%) than after pneumatic retinopexy (4% to 6.1%) or after vitrectomy with pneumatic retinopexy (11.5%).
- **Therefore, extraocular minimal buckling will require fewer reoperations and provide optimal long-term visual results [29] which will not be jeopardized by secondary complications,** such as cataract, glaucoma, etc., as would be the case after vitrectomy [30].

Consequently:
Minimal extraocular surgery,
which implies segmental buckling without drainage,
still remains the gold standard for uncomplicated detachments until less morbid procedures are invented.

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14 Reoperation of Retinal Detachments without Drainage: Minimal Extraocular Surgery as Rational Approach

14.1 Introduction

As will be recalled, the treatment of a primary retinal detachment consists of searching the break and closing it ab externo by localized buckling without drainage of subretinal fluid. As a consequence, a cerclage, pneumatic retinopexy, or a vitrectomy are avoided as primary procedures.

? **However, what should be done if the retina does not reattach after external buckling, i.e., after segmental buckling or even after a cerclage?**

? **Is there now an indication for an intraocular approach as repair, such as a gas injection or a vitrectomy with gas or silicone oil?**

▶ At this point you should recall the greater morbidity of these alternatives (see Chapter 13, pp. 299–308).

? **Why not aim first at a minimal and extraocular approach—in spite of being confronted with a reoperation?**
For example, a procedure the rationale of which you are already familiar with?

▶ Let me provide for you some facts [1].

- To begin with, analyze the borders and surface of the surgical failure and determine whether it is a rhegmatogenous detachment. This is the situation, if the detachment has convex borders and surface.
- Therefore, as in a primary detachment, you have **to search for the cause of this detachment,** i.e., **the retinal break** (see Part 1, Chapter 2.2, pp. 13–18).
- **It has to be tiny,** because otherwise it would not have been overlooked at the 1st operation.

Then this break can be treated in the same way as if it were in a primary detachment. Now you might recall the logo of our Detachment Course (Fig. 14.**1**) and the rationale behind it concerning treatment of a retinal detachment.

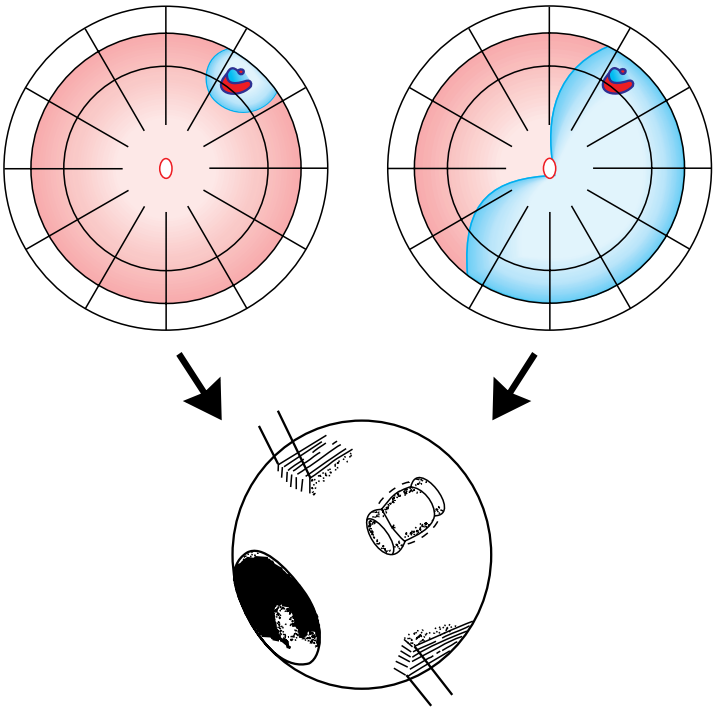


Fig. 14.1 **Minimal extraocular buckling surgery:** The treatment is limited to the area of the break and not determined by the extent of the detachment. The small *(Top left)* and the more extensive detachment *(Top right)* are caused by the same horseshoe tear at 1 o'clock. The treatment of both is the same, consisting of buckling the tear either by a radial sponge or temporary balloon without drainage of subretinal fluid.

- Therefore, also in a detachment being up for **reoperation** you will look for the break, because then it will become feasible to **limit the treatment to the area of the break**, i.e., not extending it over the entire extent of the detachment.

Consequently, the treatment of a surgical failure can also imply a rational approach representing a small procedure. To obtain a better

insight into the development of reoperations, let us review the sequence of procedures that have evolved over the last 40 years as presented in a publication by Lincoff and Kreissig [2].

14.2 History

From 1960 to 1970

Scleral buckling was the most frequent surgery for a primary retinal detachment. If the 1st **buckle** was a segmental, the 2nd operation after a failed procedure was a **larger segmental buckle**. If this failed, the 3rd operation was a **cerclage** and if this failed too, the 4th operation was **another circular band**, but this time more posterior and more constricting. The 2 encirclements, combined with 360° of coagulation, represented the limit of reoperations in those years.

? What was the rationale behind the sequence of reoperations *between 1960 and 1970*?

▶ To wall away **undetected retinal breaks** in the periphery that were presumed to be leaking.

Therefore, **"creating a new ora serrata"** became current and the described reoperations had become a routine series of procedures, representing an automatic sequence.

However, in the meantime, the techniques for retinal examination became more precise and the concession of not finding the hole was no longer valid. The availability of binocular indirect ophthalmoscopy and biomicroscopy with direct and indirect contact lenses, combined with simultaneous depression, made the retina visible up to the ora serrata.

● As a consequence **questionable holes in the retinal periphery** could no longer be a reason for applying a prospective cerclage.

After 1970 to 2000

Since the advent of vitrectomy [3] and the long-acting gases [4,5] in 1970, the vitreous has no longer been inviolate, and a new auto-

matic sequence of procedures for reoperation has evolved. The 1st operation is a **gas injection** into the vitreous and, if this fails, the 2nd operation is a **vitrectomy**. The described sequence of reoperations has become automatic.

? **But what is the rationale behind the new sequence of reoperations *after 1970 and up to 2000?***

▶ This time the failure is supposed to be due to **vitreous traction** and an intraocular tamponade of gas or, if gas fails, a vitrectomy should overcome it.

As a consequence, the patients who are referred for reoperation have mostly already had a gas injection and are being referred for a vitrectomy.

The thought which occured to us, and probably to you as well, is therefore:

? **Where does the cause of a surgical failure lie? Within the *retina* or within the *vitreous*?**

▶ To answer this question, the causes for failure were analyzed in a series of detachments.

● **At the same time 2 questions, often posed, should be answered:**
- Which type of repair will represent a rational approach?
- **Has reoperation to be a maximal procedure per se?**

14.3 Patients and Methods

A total of 752 detachments were treated with segmental buckling and without drainage [6]. In this series giant tears and perforating injuries were excluded. The detachments were caused by 1 to 3 breaks or a tear with a maximal extension of 1 clock hour. Actually they were relatively uncomplicated detachments and represented 8 out of 10 detachments that the average retinal surgeon might have to repair.

Table 14.**1** Causes of surgical failure (n = 87) after segmental buckling of 752 retinal detachments

	n	%
Another break	39	5
Inadequate buckle	27	4
"It must be traction"	17	2
Choroidals	3	
Removal of buckle	1	
Total	87	

After buckling, 87 retinas had failed to reattach. This was due to an overlooked break in 39 eyes (5%), an inadequate buckle in 27 (4%), and "it must be traction" in 17 eyes (2%) (Table 14.**1**).

If we now consider these 87 surgical failures alone, then

? **76% of failures were due to an iatrogenic error** (Table 14.**2**):
What does this imply?

▶ **45%** (39/87) were caused by **another break.**
31% (27/87) were caused by **an inadequate buckle.**

Only in 17 of the 87 eyes we were unable to find out the reason for failure. Therefore, it was suggested the term "it must be traction." In the light of this, the secondary cerclage of the 60's and 70's, that aimed at undetected breaks, was more pertinent and not so wrong. But, applying a cerclage conceded that the break could not be found, a concession that is nowadays no longer valid with the availability of the improved spectrum of diagnostic techniques (see Part 1, Chapter 2, pp. 8–25).

We should realize, at the same time, that the above findings imply the following:

? **In about 8 out of 10 eyes being up for reoperation, the cause of failure lies in:**
***An undetected break* or a *leaking break* on a buckle.**
What is the consequence of this with respect to reoperation?

Table 14.2 Relative incidence of causes of surgical failure (n = 87)

	n	%
Another break	39	44.8
Inadequate buckle	27	31.0
"It must be traction"	17	19.5
Choroidals	3	
Removal of buckle	1	
Total	87	

▶ **You should:**
- Determine the contour of the surgical failure.
- Compare it with the contour of the detachment prior to surgery.
- Search for an undetected break in the most likely area as defined by the pattern of the detachment up for reoperation [1, 2, 7].

14.4 Results

14.4.1 First Category of Surgical Failure: An Undetected Break. The 4 Rules to Find the Undetected Break in Reoperation

When the 1st category of failure, i.e., an undetected break, was examined, 4 patterns could be defined [2].
To begin with, here is an important finding which was made.

? **The buckle operation that failed can provide a clue for finding the undetected break: What does this mean?**

▶ There has been:
- **Either a change in borders** of the detachment
- **Or not.**

As you will see, both circumstances are valid to find the undetected break.

▶ 1st pattern of surgical failure due to an undetected break

Here a detachment is shown with a horseshoe tear at 10:15, which responded incompletely to a buckle beneath the break (Fig. 14.**2a**).

- The **superior border of the detachment had dropped from 11 o'clock to 9:45**:
  The inferior border had remained unchanged, indicating that the remaining fluid was not residual, but was there to stay because of **another break within 1 1/2 clock hours of the new superior border, located inferior to the buckle.**

For your recollection, Rule 1 of how to find the primary break in a primary detachment of this type is presented in Figure 14.**2b**. Biomicroscopic examination directed at this area in the detachment up for reoperation, depicted in Fig. 14.**2 a**, detected a small tear at 9:15, that was undetected at the 1st operation. The hole was too small to be seen by indirect ophthalmoscopy. For this reason, the vessel pattern around it was drawn at the biomicroscope so that we could localize this area at the operating table. Of course the break was smaller than depicted in Figure 14.**2a**. However, it should be borne in mind that when performing the reoperation, you may not find the tiny break with indirect ophthalmoscopy, but the area in which it is localized, as defined by the adjacent vessel pattern or any other retinal clue. Therefore, it is appropriate to buckle this area. When the next day the retina was reattached without drainage, it implied that the hole was buckled effectively (Fig. 14.**2c**).

? But what might you still have to do?

▶ If you have not cryopexied the break, you will have to apply laser lesions to the buckle postoperatively to secure the break.

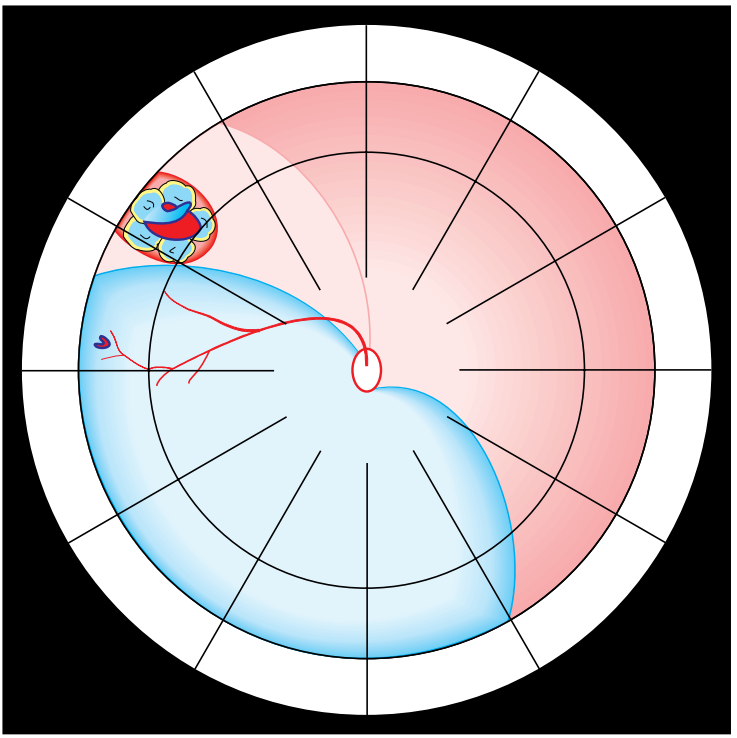


Fig. 14.**2** **1st pattern of surgical failure due to an undetected break.** **a** A superior lateral detachment 1 day after a radial buckle was placed to close a horseshoe tear at 10:15: The **upper border of the detachment had dropped** from 11:00 to 9:45, the inferior border had remained unchanged. The remaining detachment had a rhegmatogenous convex contour and extended from ora to disk. Another hole had to be present. The conclusion reached was to search for it within the area 1 1/2 clock hours beneath the new superior border which is inferior to the buckle. A **tiny** horseshoe tear—depicted larger with a surrounding vessel—was found at 9:15. This location of the hole fitted Rule 1 of how to find the primary break in a detachment (see Fig. 14.**2 b**).

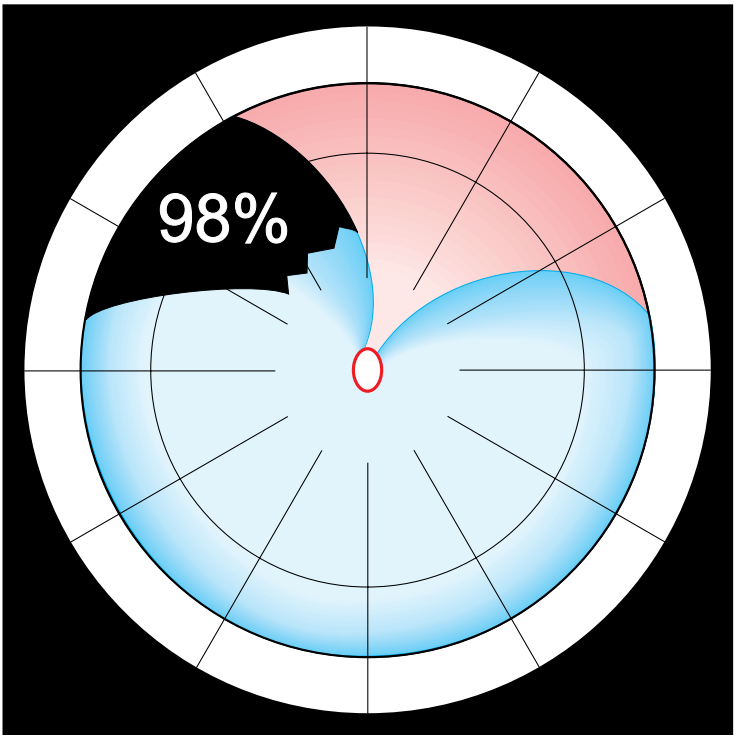


Fig. 14.**2 b** **Rule 1 for Primary Break in a Detachment.**
Superior temporal or nasal detachments: In **98%** the primary break lies within $1^1/_2$ clock hours of the higher border.

This was the 1st category of surgical failure due to an undetected break, which permits the following conclusion:

Reoperation	**Rule 1**
When the **superior border** of a temporal or nasal superior detachment **drops below the buckle,** it implies an undetected break within $1^1/_2$ clock hours below the new superior border (Fig. 14.**3a**).	

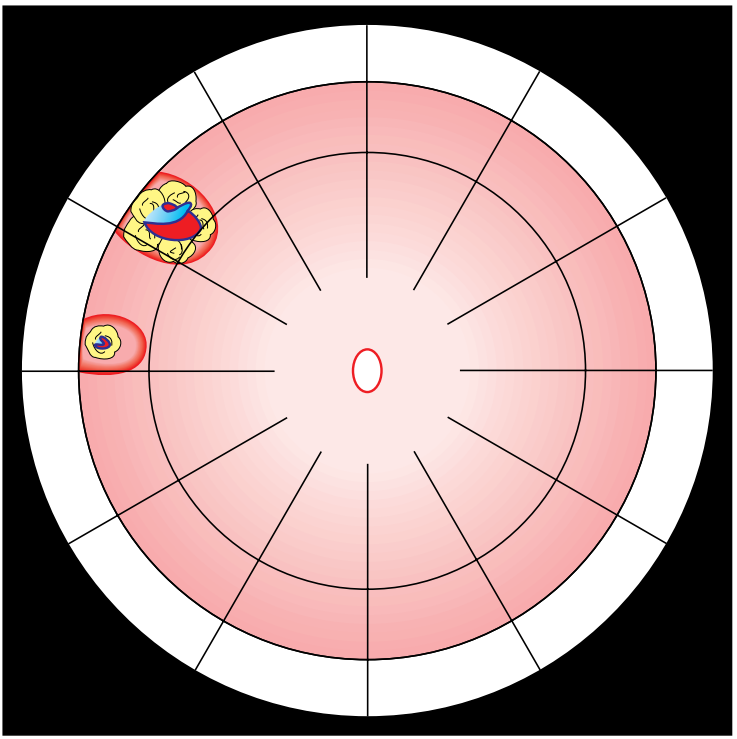
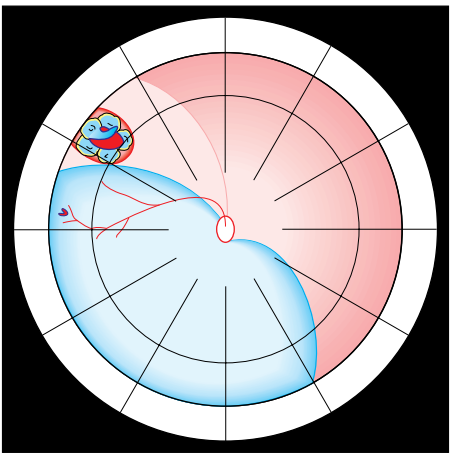
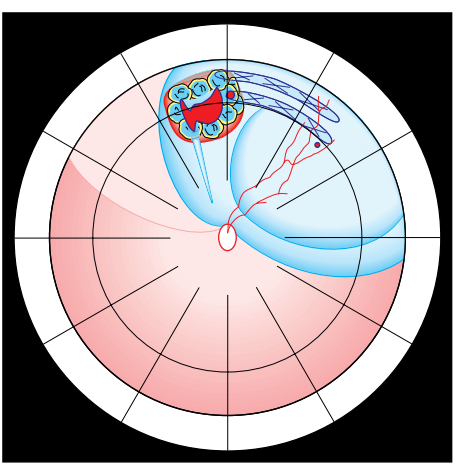


Fig. 14.**2 c** After buckling the break at 9:15 (overlooked in the detachment depicted in Fig. 14.**2 a**), the retina was reattached the next day: During surgery the area of the break was only found by the documented vessels and the tiny horseshoe tear detected after cryopexy of this area. The cryopexy lesion was pigmented 8 days after surgery.



Rule 1 for Reoperation.

When the **superior border** of a temporal or nasal superior detachment **drops** below the buckle, it implies an undetected break within 1 1/2 clock hours below the new superior border.



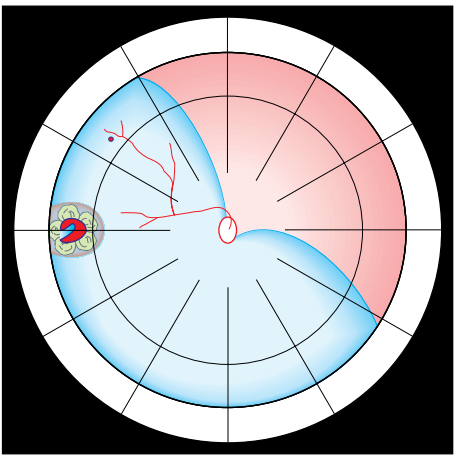
Rule 2 for Reoperation.

When the pattern of a detachment (superior, lateral or inferior) converts from **one pattern to another,** it indicates an undetected break consistent with the new pattern.

Fig. 14.3 a **Rules 1 and 2: How to find the undetected break in reoperation of a retinal detachment.**

Rule 3 for Reoperation.

When the **borders** of a detachment remain **unchanged** after a buckling operation and the buckle is in correct position, it implies an undetected break above the buckle.



Rule 4 for Reoperation.

When a **total detachment** remains **unchanged** after being encircled and drained, it implies an undetected break anterior to the existing cerclage near 12 o'clock.

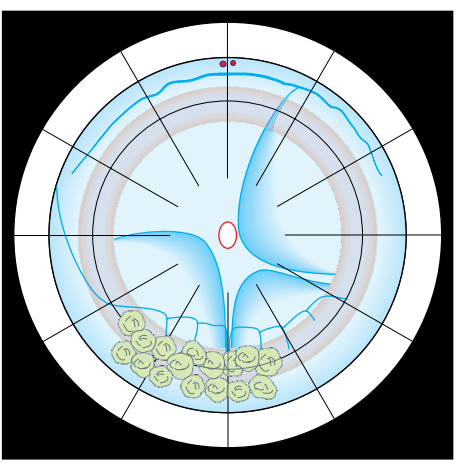


Fig. 14.3 b **Rules 3 and 4: How to find the undetected break in reoperation of a retinal detachment.**

▶ 2nd pattern of surgical failure due to an undetected break

Here you see an acute superior bullous detachment distributed on both sides of the 12 o'clock meridian. It was apparently secondary to the small hole at 12 o'clock and the larger tear temporal to it (Fig. 14.**4a**). Both tears fitted Rule 2 of how to find the break in a primary detachment (Fig. 14.**4b**). In this situation it means that the 2 identified holes are within $1^1/_2$ clock hours on either side of 12 o'clock. The retina is almost symmetrically detached on both sides. If you allowed this detachment patient to go home without double patching, this would become a total detachment just by these 2 breaks alone. Consequently, these breaks were buckled on a large radial sponge and the next day the detachment looked about the same. After 2 additional days you can recognize the minor change that is going on: There is a slight change around 11 o'clock which is hardly perceptible.

● But something else has happened, i.e., to the **pattern of the detachment**:
- Suddenly it starts to descend further on the 1 o'clock side, but on the 11 o'clock side the border of the detachment has slightly ascended.
- In addition, the bullous quality at the 12 o'clock area has diminished, but increased on the 1 o'clock side (Fig. 14.**4c**).

? What can this suggest to you?

▶
- Think for a moment and, to begin with, define the new contours of the detachment.
- **The pattern has changed.** It is no longer a symmetric detachment around 12 o'clock, but instead it has become an asymmetric detachment. It is now a superior lateral detachment.

A little later all of the fluid on the 11 o'clock side will have disappeared and the retina reattached in this area since the buckle at 11 o'clock will sufficiently have closed the 2 breaks.

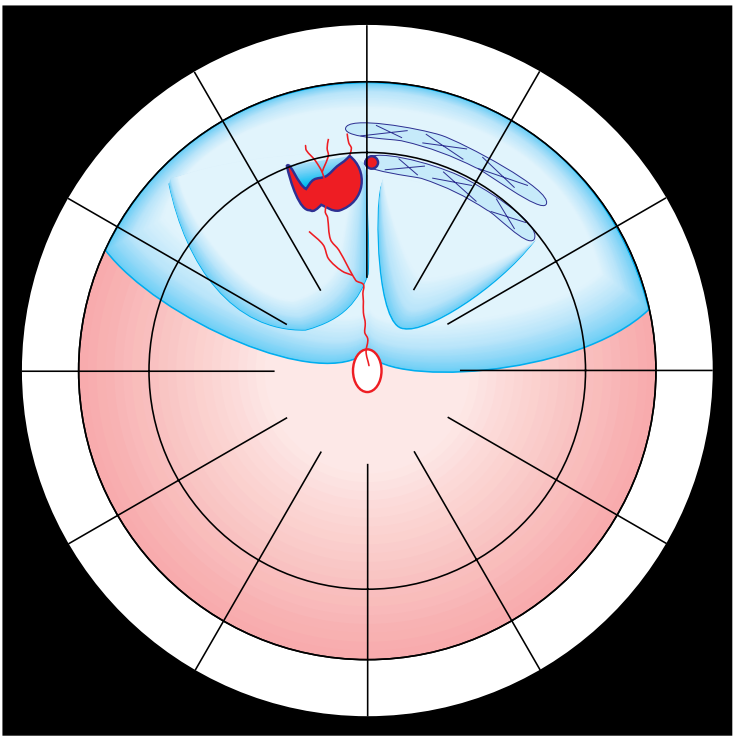


Fig. 14.**4** **2nd pattern of surgical failure due to an undetected break.** **a** A superior bullous detachment, distributed on both sides of the 12 o'clock meridian, was apparently caused by a small hole at 12 o'clock and a larger tear at 11:30. Both tears fitted Rule 2 of how to find the primary break in a detachment (see Fig. 14.**4b**).

? But what does the descending detachment on the 1 o'clock side tell you?

▶ **That on this side you have to look for another break.** You will study the lateral detachment and search within the area of 1 1/2 clock hours beneath the new border (see Fig. 14.**2b**) for a **tiny** break, because otherwise you would have found it prior to the 1st operation.

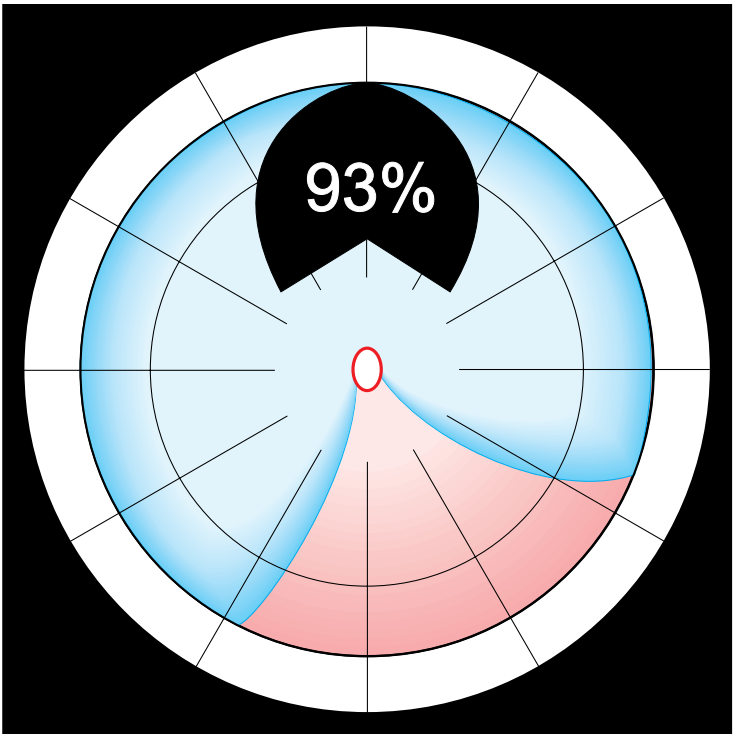


Fig. 14.**4b** **Rule 2 for Primary Break in a detachment.**

Total or superior detachments that cross the 12 o'clock meridian: In **93%** the primary break is at 12 o'clock or in a triangle, the apex of which is at the ora serrata, and the sides of which extend 1 1/2 clock hours to either side of 12 o'clock.

Biomicroscopy, concentrated on the 1 o'clock area, revealed an undetected break at 1:30 at the edge of the inferior line of lattice degeneration. The break was beyond the vessel pattern drawn to find it during reoperation, which consisted of a balloon inserted beneath the suspected area. After retinal reattachment it was concluded that the tiny hole had to be positioned on the balloon buckle (Fig. 14.**4d**). Subsequently, the entire buckled area was secured with laser lesions.

Here the conclusion obtained after analyzing the 2nd pattern of surgical failure due to an undetected break:

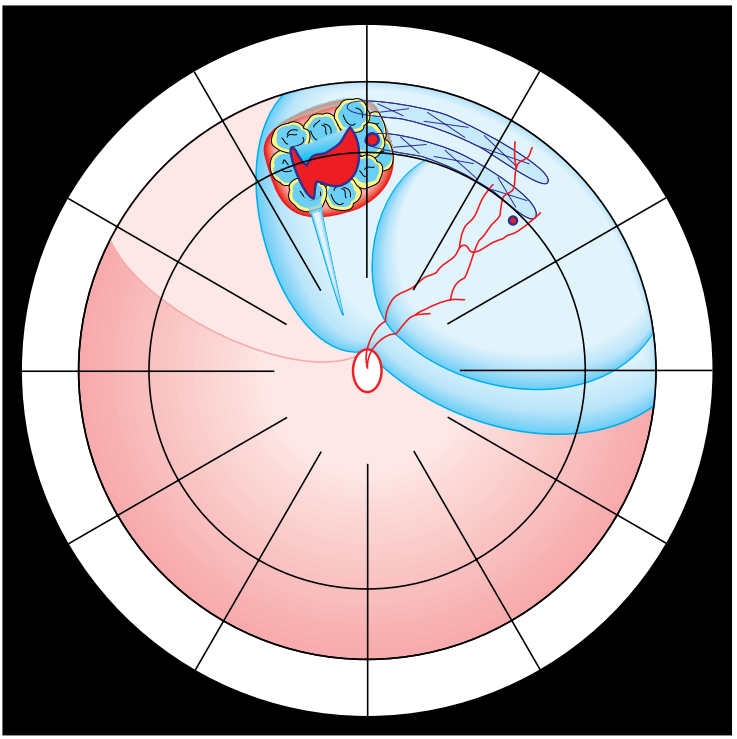


Fig. 14.**4 c** 3 days afterwards the 2 breaks in the detachment (depicted in Fig. 14.**4 a**) were buckled with a sponge and the detachment around 11 o'clock had become flatter; however, the **contour** of the remaining detachment around 1 o'clock had **changed and assumed the pattern of a lateral detachment.** Therefore, the undetected break for which one had to look, should be 1$^{1}/_{2}$ clock hours beneath the new superior border (see Fig. 14.**2 b**). A tiny hole was detected at 1:30 at the inferior line of the lattice degeneration. The neighboring vessels were drawn to find this area at the operating table.

Reoperation	**Rule 2**
When the **pattern of a detachment** (superior, lateral or inferior) **converts** from one pattern to another, it indicates **an undetected break consistent with the new pattern** (Fig. 14.**3a**).	

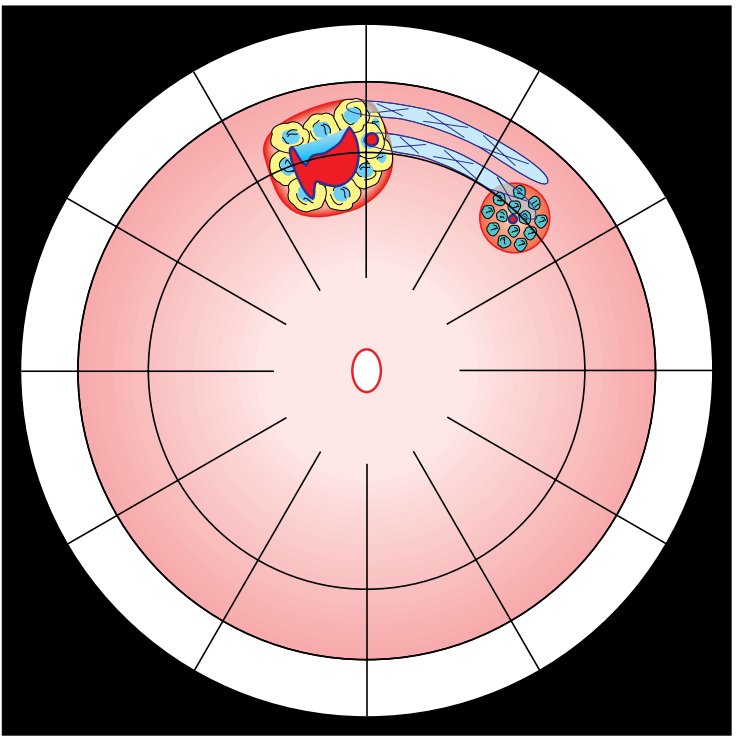


Fig. 14.**4 d** A balloon was positioned beneath the depicted area harboring the break and the retina reattached, implying that the tiny hole was on the balloon buckle. As a result, the surface of the balloon buckle was secured with laser coagulations. After the lesions were pigmented, the balloon was withdrawn and the retina remained attached during the subsequent 5 years.

- **The 2 presented surgical failures** were an example of detachments that corresponded to a primary buckling procedure with a **change of borders**.
  The character of the change directed us to the area of the undetected tiny break to be buckled in a reoperation.

3rd pattern of surgical failure due to an undetected break

In this surgical failure a horseshoe tear at 9 o'clock was buckled and the borders remained unchanged (Fig. 14.**5a**). The buckle was correctly placed under the horseshoe tear at 9 o'clock.

? What should you do now? What is wrong?

- Reflect for a moment and you will realize that the buckled tear was located more than 1 1/2 clock hours beneath the superior border of the lateral detachment.
- Your chances of succeeding with a buckle in this location will be—as you might recall—only 2% (see Fig. 14.**2b**).

? What does this imply? What will you have to do now?

- You should look with biomicroscopy for an **additional hole within 1 1/2 clock hours** beneath the superior border of the detachment, i.e., located above the existing buckle.
- The hole will be **tiny** because otherwise you would not have overlooked it.

After detecting a break at 10:15 at the biomicroscope, the neighboring vessels were drawn again to detect it with indirect ophthalmoscopy during surgery. After cryopexy and placing a balloon under the depicted area, the retina was reattached without drainage of subretinal fluid the next day (Fig. 14.**5b**). The balloon was withdrawn after pigmentation of the cryopexy lesions.

And here is the conclusion after analyzing the 3rd pattern of surgical failure due to an undetected break:

Reoperation **Rule 3**

When the **borders of a detachment remain unchanged** after a buckling operation and the buckle is in the correct position, this implies **an undetected break above the buckle** (Fig. 14.**3b**).

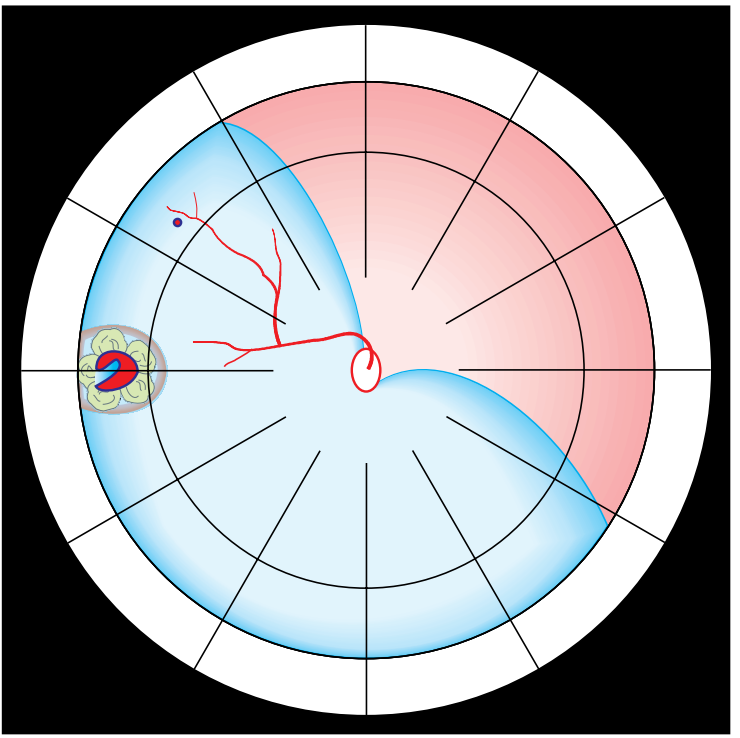


Fig. 14.5 **3rd pattern of surgical failure due to an undetected break. a** A superior lateral detachment, extending from 4 over 6 to 11 o'clock was unchanged 2 days after a horseshoe tear at 9 o'clock was buckled. **The contours did not change.** The conclusion reached was that the tear at 9 o'clock was buckled correctly; however, its location was not within the area of probability in which the primary break in a superior temporal detachment should be located (see Rule 1 in Fig. 14.**2 b**). Instead the buckled tear was located 2 clock hours beneath the superior border and not within the $1^1/_2$ clock hours. A tiny hole at 10:15 was detected with the biomicroscope within the area of probability to harbor the break. The neighboring vessels were drawn to detect this area during reoperation.

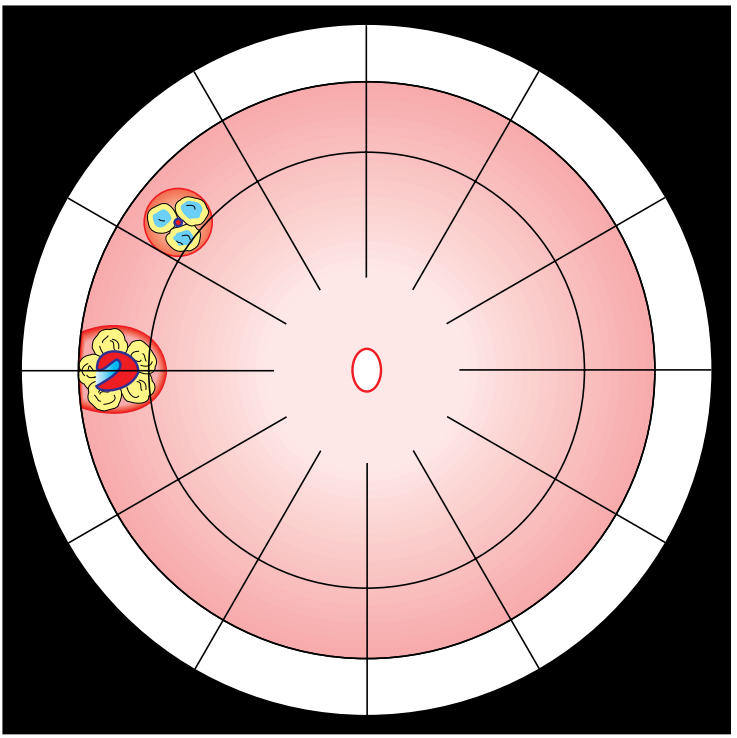


Fig. 14.**5 b** The area at 10:15, depicted preoperatively, was cryopexied and the break thereby found and supported by a temporary balloon. The retina reattached. After pigmentation of the cryopexy lesions, the balloon was withdrawn.

▶ 4th pattern of surgical failure due to an undetected break

Now we see a total detachment which remained unchanged after 2 encircling operations with drainage of subretinal fluid, more than 2 years before (Fig. 14.**6a**). The previous operations had concentrated on some lattice degenerations between 5 and 8 o'clock, and this area was heavily coagulated. A cerclage was added, presumably to cover a possible break elsewhere and perhaps to release traction.

When examining a total detachment that has been drained, with the fluid reaccumulating superiorly in the periphery of a cer-

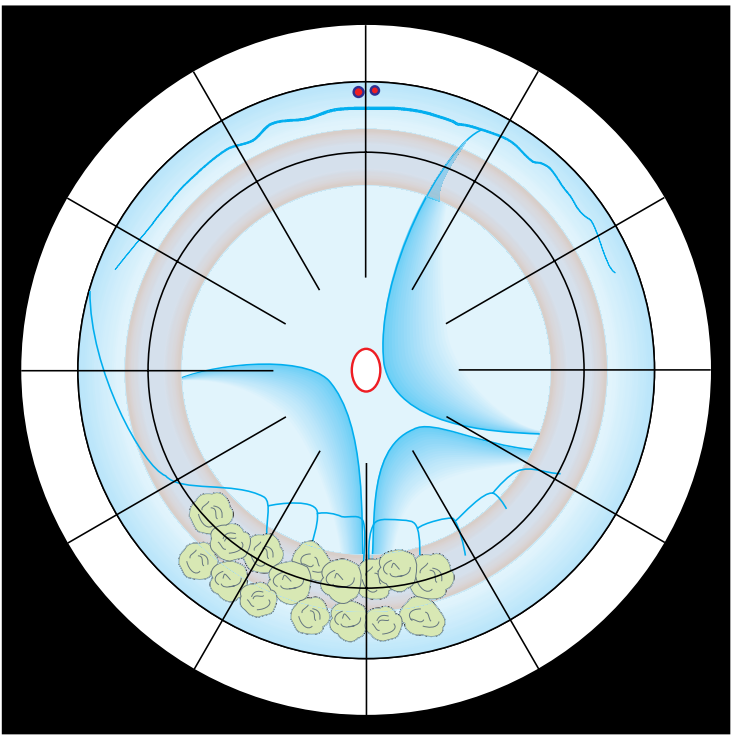


Fig. 14.**6** **4th pattern of surgical failure due to an undetected break. a** This total **detachment had remained unchanged** after 2 encircling operations with drainage of subretinal fluid and coagulation of lattice degenerations between 5 and 8 o'clock. This patient was sent to Prof. Lincoff (New York) for reoperation. Since the retina was detached anterior to the cerclage at 12 o'clock, according to Rule 2 of how to find the primary break in a detachment (see Fig. 14.**4 b**), 2 tiny round holes were detected near the ora serrata at 12 o'clock.

clage, you should recall Rule 2 of how to find the break in a primary detachment that crosses the 12 o'clock meridian (see Fig. 14.**4b**). In such a detachment the primary break should lie within a triangle, the apex of which is close to the ora serrata at 12 o'clock. With biomicroscopy and depression, 2 small round holes at 12 o'clock near the ora

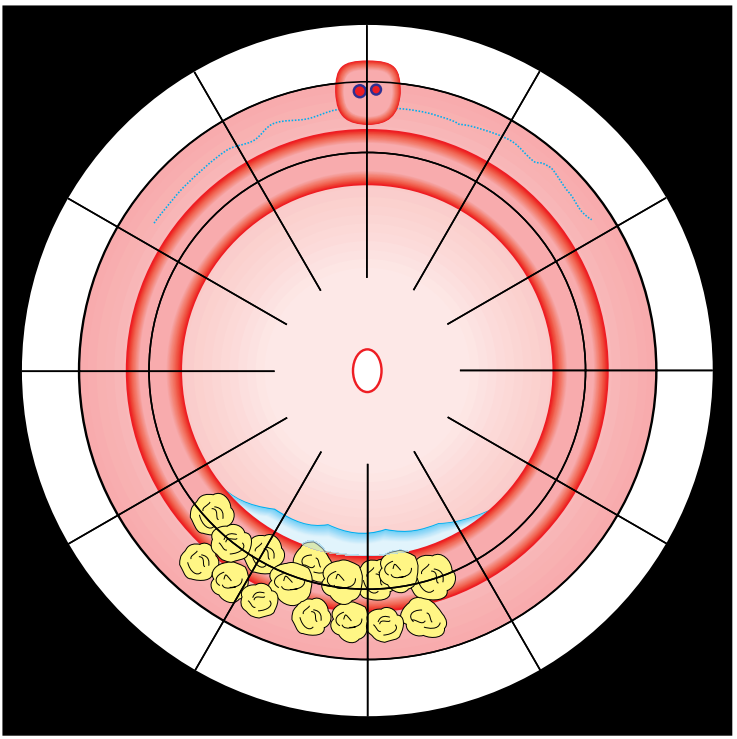


Fig. 14.**6 b** 1 day after placing a radial buckle without drainage beneath the 2 round holes anterior to the cerclage, the retina reattached. Laser lesions were subsequently added to secure the 2 holes stretched out on the buckle. The small residual tractional detachment posterior to the cerclage at 6 o'clock disappeared after a few weeks. Reattachment was sustained in spite of the fact that the encircling band was subsequently cut.

serrata were detected. Prominent structures in close proximity were documented to define the location of the 2 tiny holes and to detect this area at the operating table. Afterwards this area was supported by a radial sponge buckle without drainage and the retina reattached (Fig. 14.**6b**). Subsequently, the entire surface of the radial buckle har-

boring the 2 holes was secured by laser lesions. The small residual tractional detachment close to the cerclage at 6 o'clock disappeared after a few weeks.

- **At this moment it should be recalled that this eye had already undergone 2 unsuccessful cerclage operations with extensive diathermy.**
- In contrast to the preceding operations, this 3rd operation consisted of a minimal extraocular and rational approach, i.e., of
- **Placing a buckle at 12 o'clock under the holes in local anesthesia;**
  which resulted in retinal reattachment.

And here is Rule 4 for reoperation of a surgical failure due to an undetected break:

Reoperation	Rule 4
When a total detachment remains unchanged after being encircled and drained, it implies **an undetected break anterior to the existing cerclage near 12 o'clock** (Fig. 14.**3b**).	

14.4.2 Second Category of Surgical Failure: An Inadequate Buckle. The 3 Reasons for an Inadequate Buckle

As you will recall, 31% of primary failures were caused by an inadequate buckle [2]. The buckle was not placed correctly, which is easy to correct. There are 3 reasons for an inadequate buckle. It is either poorly placed in relation to the break, too narrow, or not high enough. This actually is the order of frequency and a buckle not being high enough is a rare exception (in only 6 out of 752 detachment operations did the buckle seem not to be high enough, i.e., its frequency is less than 1%).

1st reason for an inadequate buckle:
A poorly placed buckle in relation to the break or breaks

In this detachment (Fig. 14.**7a**) only the upper edge of the horseshoe tear at 3 o'clock is sufficiently tamponaded by the buckle. As a re-

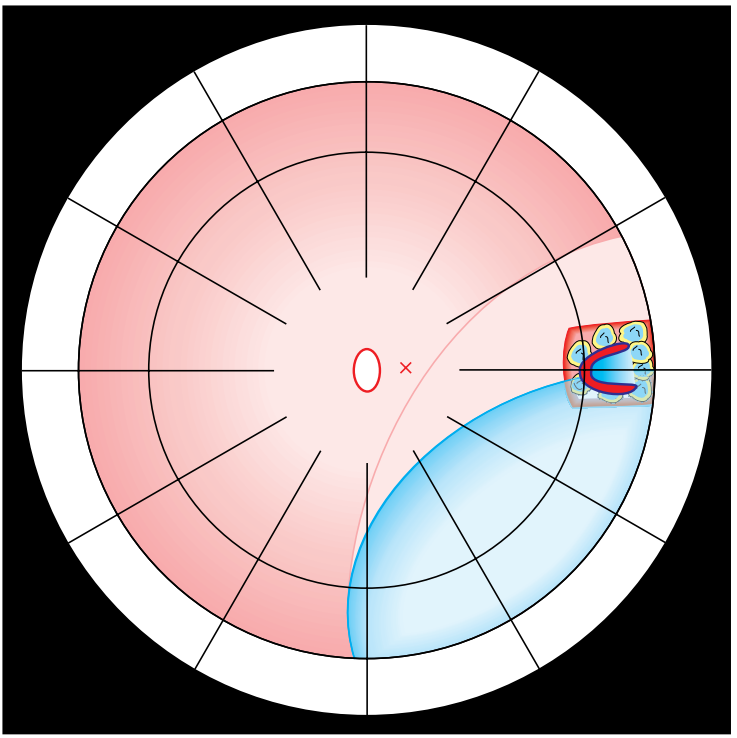


Fig. 14.7 **1st reason for an inadequate buckle: A poorly placed buckle in relation to the break(s): a** The horseshoe tear at 3 o'clock was the only tear in the lateral detachment; however, the sponge was not placed correctly under the horseshoe tear. As a result, the **contour of the detachment changed,** however, the inferior part of the horseshoe tear was still leaking, causing a residual rhegmatogenous detachment.

sult, subretinal fluid superior to the buckle has absorbed, but inferior to the buckle the detachment has persisted. The contour had changed and the detachment receded. However, the new shape of the detachment indicated where the tear was leaking. The tear was poorly supported inferiorly by the buckle, which had to be enlarged. Of course you can use a larger buckle, but representing already a large buckle (7.5 mm sponge) and enlarging it by placing instead

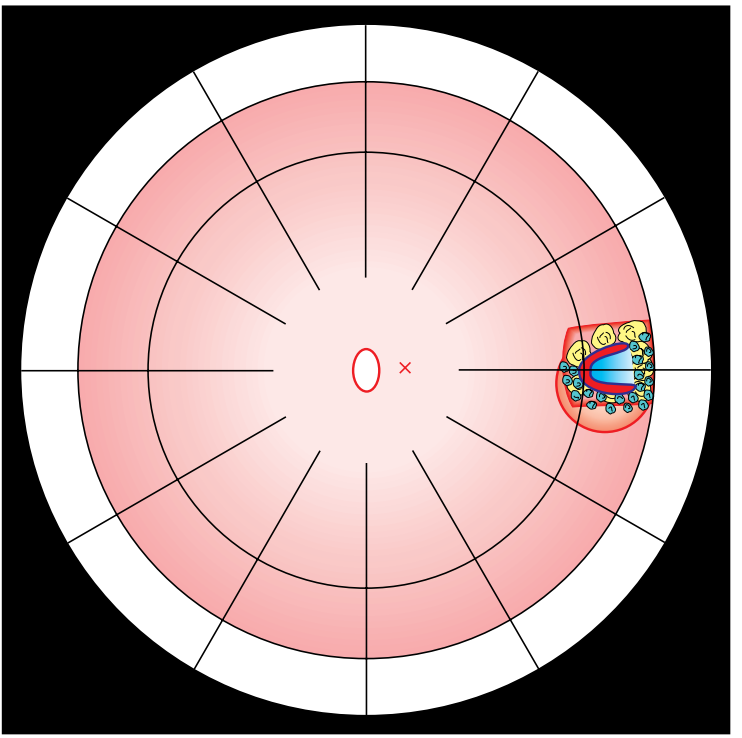


Fig. 14.**7 b** A temporary balloon was placed on top of the existing buckle to increase its buckling effect. The inferior edge of the tear then reattached and subretinal fluid disappeared. Since complete reattachment of the horseshoe tear was achieved 4 days after surgery, the delayed reattached edges were additionally secured by laser lesions. The balloon was left in place until pigmented scars had developed. After removal of the balloon, the retina remained attached.

2 radial 7.5 mm sponges side by side might not only cause diplopia in an eye in which full visual acuity can be expected (macula preoperatively attached), but also a secondary iris atrophy.

- Instead of a broader buckle, an intraocular gas injection could be considered.
- But as another alternative, being an extraocular procedure, a temporary balloon was placed on top of the buckle to increase its indentation. The retina subsequently reattached completely (Fig. 14.**7b**).

Here as well, do not forget to add laser lesions at these edges of the tear in which delayed reattachment had occurred.

- **Reoperation** of this surgical failure was aimed at compensating for an **incorrectly placed buckle**, causing leakage at one edge of the tear.
  The temporary balloon was used to enlarge the buckle and, after reattachment, to provide a sustained tamponade during the period of scarring.

As reoperation the temporary balloon buckle represented the easiest solution and, at the same time, the least morbid procedure.

2nd reason for an inadequate buckle: A correctly placed buckle, too narrow in relation to the break or breaks

This detachment with 4 horseshoe tears was treated by a 4 mm circumferential sponge without drainage of subretinal fluid. To buckle all of the tears sufficiently, the buckle is too narrow for a sufficient tamponade. On the 1st postoperative day subretinal fluid had dropped to the inferior edge of the most superior tear and the 3 tears below remained open (Fig. 14.**8a**). Four days later there was no change and consequently the buckle was enlarged by raising it by a balloon. This was attempted by inflating a balloon on top of the existing buckle. The second tear was subsequently closed off and the upper border of the detachment fell below (Fig. 14.**8b**). When the balloon was inflated with an additional 0.6 ml, thus raising the buckle further, the remaining 2 tears closed off and the entire retina reattached (Fig. 14.**8c**). Laser lesions then had to be applied around the tears.

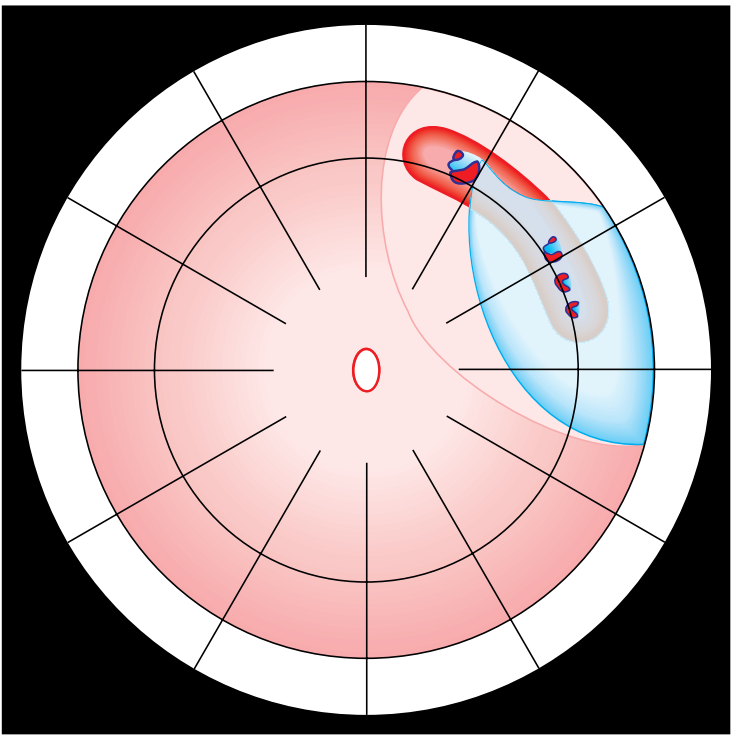


Fig. 14.8 **2nd reason for an inadequate buckle: A buckle correctly placed, but too narrow in relation to the break(s). a** 4 horseshoe tears of different size and at different distance from the ora serrata were treated with a narrow 4 mm circumferential sponge without drainage of subretinal fluid. On day 1 after surgery the **detachment had only receded to the inferior edge of the superior horseshoe tear,** being inadequately placed on the circumferential buckle (the operculum was not sufficiently supported, the buckle was too narrow). Only the superior portion of the horseshoe tear was tamponaded. The cryopexy lesions are not depicted to provide better identification of the various tears and the changes in contour of the detachment.

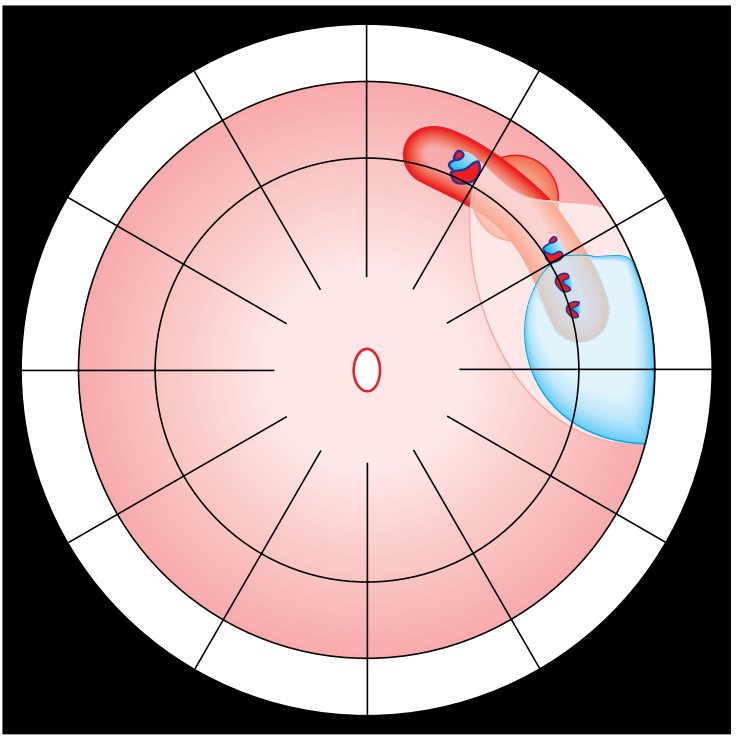


Fig. 14.**8 b** After inserting a balloon to elevate the narrow buckle, the horseshoe tear at 1 o'clock reattached and the **detachment receded beneath the 2nd tear at 2 o'clock.** The 2 inferior horseshoe tears were still detached.

- **The ability to increase, as needed, the size of an inserted balloon buckle after it is in place,** proved an additional advantage of the balloon procedure, thus **to avoid another operation** (see Fig. 9.**14**).

To begin with, one is able to perform an extraocular and minimal procedure as reoperation. If an additional reoperation should be needed to enlarge the buckle further, it can be done without delay

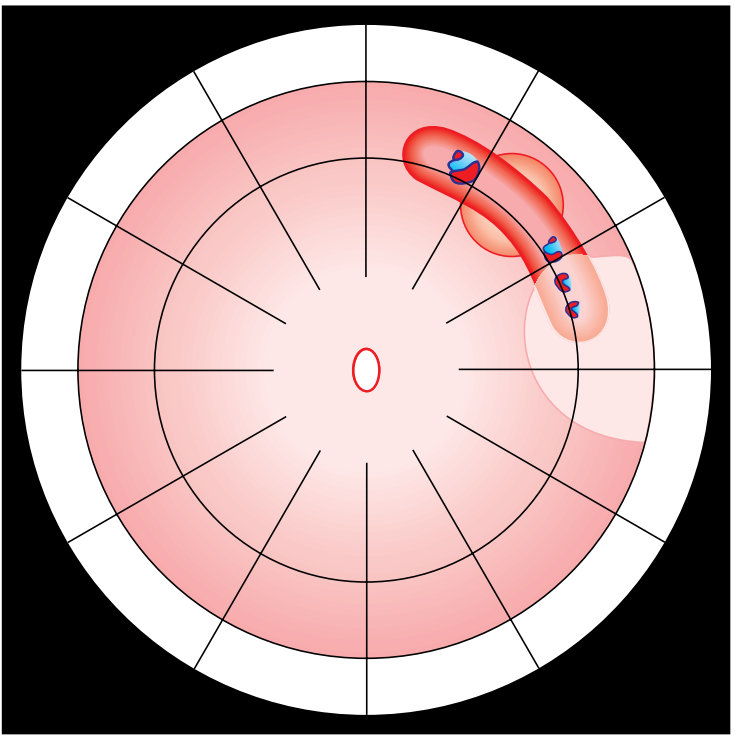


Fig. 14.**8 c** The balloon was inflated on 2 successive days, with 0.3 ml of fluid in each case, to raise the buckle further, whereupon the **2 remaining tears closed off and the retina reattached** completely. Subsequent laser lesions had to be applied around the horseshoe tears which were reattached delayed. After pigmentation of the lesions the balloon was removed.

and without reopening the eye, again, just by injecting more fluid via the valve into the inserted balloon and thus increasing its tamponading effect.

▶ **3rd reason for an inadequate buckle:**
A correctly placed buckle, not high enough in relation to the break or breaks

Here we have a very bullous, almost taut detachment with 2 breaks at the edge of a lattice degeneration, very posteriorly located. The

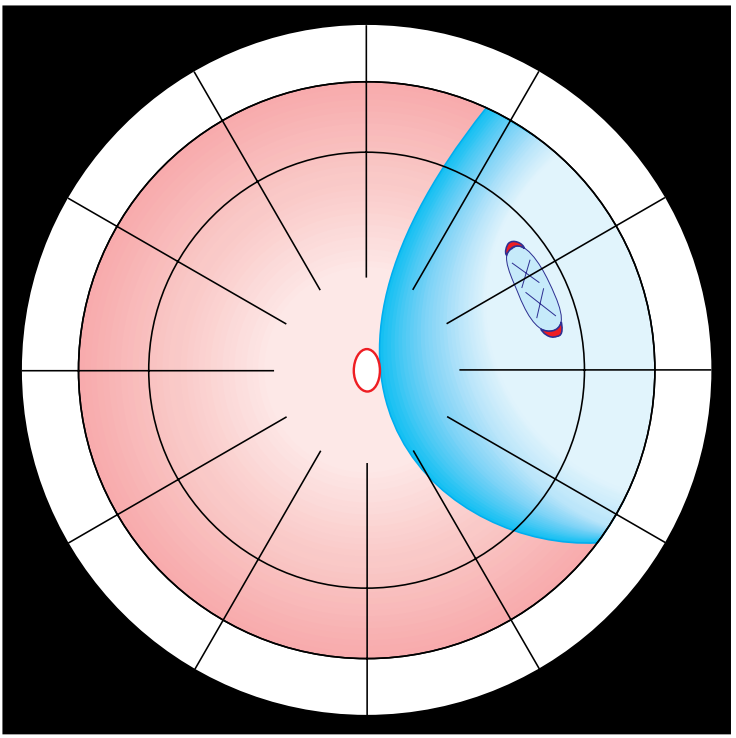


Fig. 14.**9** **3rd reason for an inadequate buckle: A buckle correctly placed, but not high enough in relation to the break(s). a** The 2 breaks at the lateral edges of lattice degeneration are posteriorly located, i.e., on the higher portion of the bulla.

breaks are on the very high portion of the bulla (Fig. 14.**9a**). If these breaks had been located more anteriorly, the retina would not have been as highly elevated. A 5 mm circumferential sponge was tied in and correctly placed beneath these breaks. However, the next day and as well after 4 days there was no change (Fig. 14.**9b**). It was again confirmed that there was no additional hole to be found neither anterior, superior, nor posterior to the buckle. It was then concluded that the buckle was not high enough for this posterior group of breaks.

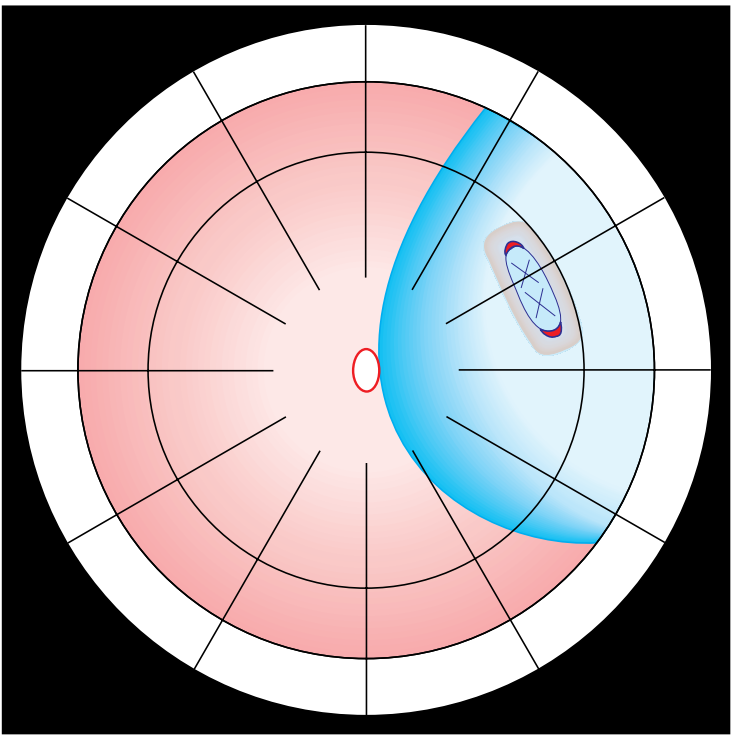


Fig. 14.**9 b** After a 5 mm circumferential sponge was tied in and correctly placed beneath the 2 breaks, even 4 days postoperatively **no change had occurred.** It was ascertained that there was no additional break anterior, superior, or posterior to the buckle. As a result, it was concluded that the buckle was not high enough for this posteriorly located group of breaks. *This finding represents a rare exception,* i.e.: *A 5 mm sponge in correct position, but not high enough to close off the break(s).*

Actually this is a rare finding:

That the buckle is in correct position,
but the retina does not settle.

This is actually only the case **in less than 1%**.

Ultrasonography confirmed that there was still the same level of separation between the detached retina and the buckle after 4 days.

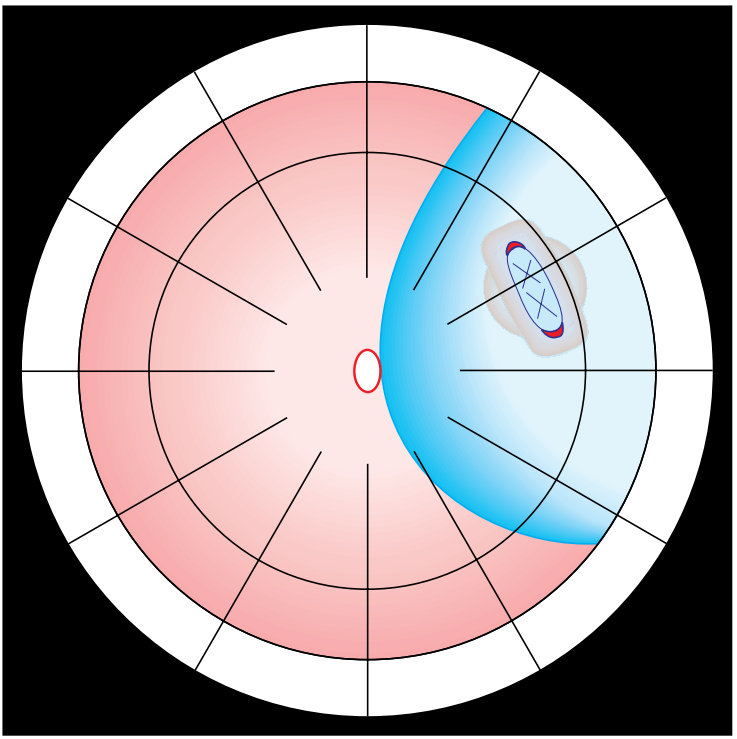


Fig. 14.**9 c** After a balloon was inserted on top of the existing sponge and inflated with 0.5 ml of fluid, the **buckle was raised further but there was no change** and the retina did not reattach.

? What can be done?

▶ — You could inject some **gas**, preferably Xenon gas, to flatten the retina.
— Or you could **drain**.

? But both procedures, however, would harbor a greater morbidity, than what?

▶ A **temporary extraocular balloon** being inserted on top of the existing buckle.

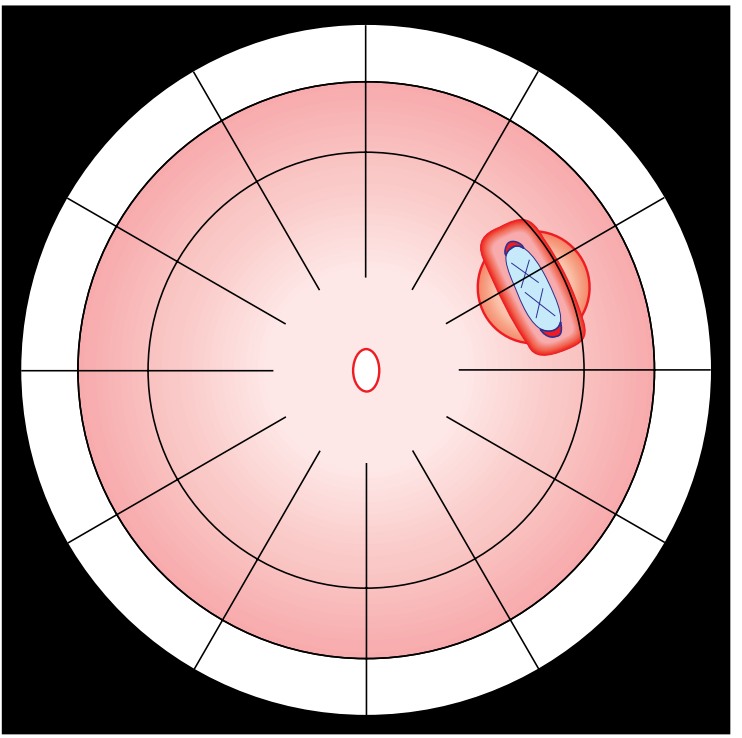


Fig. 14.**9 d** After an additional 0.4 ml of fluid was added to the balloon volume, which **increased the buckling effect further, closed off the breaks**, and the retina reattached. As well, in this situation subsequent laser lesions had to be added to secure the breaks since delayed reattachment occurred.

After 0.5 ml of fluid was added to the balloon volume, the buckle was slightly elevated; however, there was still no change (Fig. 14.**9c**). The next day another 0.4 ml of fluid was added and the buckle further raised, resulting in retinal reattachment the next day (Fig. 14.**9d**).

? What will be your conclusion as to the treatment of the next, rare detachment like this?

- Either primarily you will select a larger sponge
- Or you will add a temporary balloon—for the rare occasion—to raise secondarily the buckle to obtain retinal reattachment.

The described 3 patterns of an inadequate buckle are easy to diagnose and they are even more easy to correct. This can be done preferably by a temporary balloon, either to enlarge or to raise the existing buckle, and this minimal extraocular procedure will suffice as reoperation. The other 2 alternatives as reoperation would be a gas injection into the vitreous or increasing the buckle height by using a larger sponge or a cerclage; yet both procedures harbor a greater morbidity.

The 2 categories of surgical failure, the undetected break and the inadequate buckle, make up 76% of failures. Therefore, it is mandatory to correctly interpret the surgical failure, i.e., to begin with, to define its contours and thus its rhegmatogenous origin.

As a result, the 2 main causes of a surgical failure, i.e., about 8 out of 10 failures, can be exactly defined and corrected by a minimal extraocular approach, if the undetected or leaking break is found.

14.4.3 Third Category of Surgical Failure: "It Must Be Traction"

The last category "it must be traction" was the cause for surgical failure in 2% after a primary buckle operation. It constituted 17 detachments or 19.5% of all the failures, i.e., 2 out of 10 failures were due to probable traction. The traction could take the following forms: 1. "Immobile" retina, 2. subsequent starfolds which caused redetachment of a buckled break or which 3. progressed into a massive proliferative vitreoretinopathy.

1. **If the retina appears "immobile"** the first thought crossing your mind should be:
   ➜ **Raise the buckle** (see Fig. 14.**9**),
   but with the proviso that you are certain that no break was overlooked.

2. **If a reattached tear on the buckle will redetach** due to increased traction on the operculum or due to a secondary starfold posterior to it:
   ➜ **Enlarge the buckle or raise it permanently by a cerclage**
   which might succeed in reattaching the retina. If reattachment results, apply extremely light and interrupted laser lesions at the reattached edges of the tear so as not to provoke further progression of PVR.
3. **If massive proliferative vitreoretinopathy** is developing:
   ➜ **Perform vitreoretinal surgery.**

14.5 Conclusion

The most surprising finding in analyzing the surgical failures (n = 87) of 752 detachments treated by segmental buckling without drainage was that 76% of them were caused by an undetected or inadequately supported break. This cause of failure can be easily diagnosed and corrected. The procedure for correction can again represent an extraocular minimal approach with local buckling aimed at closing the break. This procedure of low morbidity is therefore feasible in 8 out of 10 surgical failures.

- **Therefore, it is up to you:**
  - To analyze the detachment up for reoperation, to define the reason for failure, and to search for the undetected break.
  - To select the adequate procedure with a minimum of morbidity to reattach the break.

The most important diagnosis when studying a surgical failure with convex contours is to determine whether there had been a **change or no change in contours** after the preceding operation. This finding will help you to locate the undetected break which can then be closed by a local buckle as well.

- Consequently:
  - **When an undetected break is found in a surgical failure, this does not portend a bad prognosis.**
  - **Instead it implies that again you can tamponade this break by a small extraocular procedure.**
  - Therefore, do not over-react because "there might be more undetected breaks" (better search for them!) or because it is a surgical failure up for re-operation.

An inadequate buckle is the next most common cause for failure. This is relatively easy to determine and to correct, because you know already what did not work.

- Consequently:
  - **A better placement of the buckle, a broader or a higher buckle will be required.**
  - Again, do not over-react because "there might be traction."

If the retina starts to redetach, i.e., due to an anterior leakage of a horseshoe tear after a primary reattachment or due to a subsequent starfold posterior to the tear, you might decide, only as an exception, upon a cerclage to permanently raise a buckle.

- **However, you should never use a cerclage just because it is a reoperation:**
  Its prophylactic value in combating invisible traction is most doubtful.
- In addition, we inject gas much less frequently than we did 15 years ago which is due to its morbidity [5].
- **Consequently, you should:**
  - **Not inject gas just because it is a reoperation.**
  - **The same is true for a vitrectomy.**

Over the years we have become convinced that an intravitreal gas again forces the cortical vitreous—which is already detached (with few exceptions, e.g., oral disinsertion) in rhegmatogenous detach-

ments—back against the surface of the retina where it tends to adhere, proliferate, cause PVR, and redetach the tear [8].

Admittedly, a gas injection as an arbitrary reoperation will sometimes reattach the retina, but only providing there is not another break present.

But keep the following in mind:
- **An arbitrary gas injection is currently the most frequent cause of PVR.**
- **An arbitrary vitrectomy**—as paradoxical as it might sound—**is probably the second most frequent cause of PVR** in the course of a rhegmatogenous detachment (see Chapter 11, pp. 271–287 and Chapter 13, pp. 299–308).

Admittedly, the last statement that an arbitrary vitrectomy might be a cause for failure due to PVR, is a statement which is hard to accept, when even a vitrectomy as primary procedure for a detachment is in discussion. However, you might still recall the previous statement when you are planning a reoperation. Instead I would like to imprint in your mind the following considerations:

? When confronted with a reoperation, try to aim at the smallest solution first. How?

- Analyze the contours of the detachment to define whether it is a failure of rhegmatogenous origin. If this is the situation:
- Search for the undetected or leaking break.
- Close it by a minimal extraocular approach.

Remember that in the long-run this can be favorable for the eye and its future visual function. At the same time you should recall that by this minimal extraocular surgery you will not jeopardize the prognosis of this eye, because if you should not succeed, you could at any time convert the treatment into a more invasive procedure.

As you might have experienced, it is most difficult to evaluate whether there is a very substantial vitreous traction if you cannot confirm this with ultrasound or biomicroscopy.

An indication for vitrectomy as reoperation is given:
- If the retinal break could not be closed off by a buckle in a rhegmatogenous detachment, even after being raised by a cerclage.
- Or if massive proliferative vitreoretinopathy has developed.

- **But bear in mind that vitrectomy as repair of a surgical failure will represent the exception.**
- **It should not represent a routine procedure for reoperation.**

14.6 Checklist for Reoperation as Minimal Approach

After analyzing the surgical failures, let me present to you the following guidelines as checklist for your clinical practice.

Checklist for reoperation of surgical failure:
- If there is another break due to the rhegmatogenous contour,
  ▶ **Find and close the break.**
- If the residual rhegmatogenous detachment indicates that there is an inadequate buckle,
  ▶ **Correct the buckle.**
- If a horseshoe tear starts to redetach after reattachment on a buckle,
  ▶ **Raise the buckle or add a cerclage.**
- If, in spite of a high radial buckle or an additional cerclage to raise the buckle, the horseshoe tear cannot be closed off and you are certain that you have not overlooked another break superior to it,
  ▶ **Decide upon a vitrectomy.**
- If there is a detachment with PVR grade C_1 or C_2,
  ▶ **Try buckling the break first** (see Part 1, Chapter 8.18.2–8.18.5, pp. 257–277).
- If there is a detachment with massive PVR,
  ▶ **Perform vitreoretinal surgery.**
- If, in spite of meticulous diagnostics, you cannot find the missing break indicated by the convex contour of the surgical failure, do not over-react, and, instead,

- **Search for the break in the area of probability preoperatively and intraoperatively:**
  - If no break is found, place an external segmental buckle in the area of probability.
- **Or decide upon a diagnostic gas bubble:**
  - Use the descending phase.
  - And use the ascending phase as well, if you are still uncertain about the meridian of the break.

– If you did not find the break by the diagnostic gas bubble,
- **Do not rely upon the fact** that you will find the break intraoperatively during vitrectomy by the so-called **schlieren phenomenon**:
  - Remember that it must be a tiny break from which a schlieren phenomenon will not develop.

– If, after all, you are still convinced—due to the convexities—that there must be another break,
- **Do not move this problem into the operating room:**
  - To find during that time the break, or if you are not successful
  - To move on to an extensive intraocular surgery to obtain retinal reattachment by an internal tamponade.

– **Instead:**
- **Give yourself the chance to find a rational approach as reoperation,** i.e.,
- **Re-study the retina for another day:**
  - Define the area or areas most likely to be harboring the break.
  - Analyze the retinal drawings recorded prior to the preceding operation(s).
  - Or, as a last resort, discuss your findings with others or with the previous surgeon who might provide a clue to a more rational and limited approach as reoperation.

These are the tips I would like to give you when being confronted with the challenging situation of a reoperation.

Because here as well:

“Less is more”.

And as already postulated for a primary operation, the same is true for a reoperation:

- **A small reoperation to reattach a retina is better than a large one,**
- **Two small reoperations are better than 1 large one.**

And this is of great importance when considering the long-term visual function of the reoperated eye and, in particular, when being aware of the increased life expectancy our patients will have.

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